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Environmental Assessment of Buccaneer Gas and Oil Field in the Northwestern Gulf of Mexico 1978-1979. Volume VI. Currents and Hydrography of the Buccaneer Field and Adjacent Waters

(U.S.) National Marine Fisheries Service
Galveston, TX

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16. ABSTRACT Four seasonal hydrographic surveys were conducted in the vicinity of the Buccaneer Oil Field in an effort to describe the physical environment in and around a producing oil and gas field. The measurements made included currents, wind, waves, total suspended solids, and hydrographic parameters including temperature, salinity, conductivity, dissolved oxygen, pH, and transmissivity. The results of the study indicated that the area can best be described as a mixing zone for coastal and offshore waters. The mixing of water masses resulted in salinity variations as great as 3.6 ppt across the 6-mile study area. The area is also a high energy regime with considerable scouring from waves and currents but also with a potential for sedimentation during the more quiescent periods. The measured currents frequently exceeded 40 cm/sec and occasionally exceeded 60 cm/sec. The changing currents which are influenced by the tides, winds, and shoreline, continually shift the location of the mixing zone. Consequently the extent of the penetration of the fresh coastal water and therefore the distribution of salinity and temperature are quite variable. This variability in conjunction with the normal seasonal changes results in a variable hydrographic environment.

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Environmental Assessment of Buccaneer Gas and Oil Field In the Northwestern Gulf of Mexico, 1978-1979

VOL. VI - CURRENTS AND HYDROGRAPHY OF THE BUCCANEER FIELD AND ADJACENT WATERS

BY

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Volume VI - CURRENTS AND HYDROGRAPHY

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LIST OF VOLUMES

This Annual Report is printed in ten separate volumes:

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Principal Investigators

Work Unit 2.2.3 — Implement, Monitor, and Modify Data Management System

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Volume II - SEDIMENTS AND PARTICULATES

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Volume III - FISHES AND MACROCRUSTACEANS

Work Unit 2.3.5 — Effect of Gas and Oil Field Structures and Effluents on Pelagic and Reef Fishes, Demersal Fishes, and Macrocrustaceans

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Volume IV - BACTERIA

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Volume V - FOULING COMMUNITY

Work Unit 2.3.8 — Effects of Gas and Oil Field Structures and Effluents on Fouling Community Production and Function

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Volume VI - CURRENTS AND HYDROGRAPHY

Work Unit 2.3.9 — Currents and Hydrography of the Buccaneer Field and Adjacent Waters

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Volume VII - HYDROCARBONS

Work Unit 2.4.1 — Hydrocarbons, Biocides, and Sulfur

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Volume VIII - TRACE METALS

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Volume IX - FATE AND EFFECTS MODELING

Work Unit 2.5.1 Sources, Fate and Effects Modeling

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Volume X - HYDRODYNAMIC MODELING

Work Unit 2.5.2 Hydrodynamic Modeling

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GUIDE TO USERS OF THE ANNUAL REPORT

Volume I (SYNOPSIS/DATA MANAGEMENT) of the Annual Report is designed to be used as a briefing document and as a key to more detailed scientific and technical information contained in Volumes II through X. Objectives, methods and results for each work unit are summarized in greatly abbreviated form within Volume I to facilitate dissemination of information. Thus, Volume I can be used alone or as a reference to companion Volumes II through X. Complete citations for literature cited in Volume I can be found in the Volumes II through X in which the detailed work unit reports are presented.

It is hoped that such an approach to environmental impact information dissemination will make the Annual Report a more useful and widely read document.

FOREWORD

Increased petroleum development of the outer continental shelf (OCS) of the United States is anticipated as the U.S. attempts to reduce its dependency on foreign petroleum supplies. To obtain information concerning the environmental consequences of such development, the Federal Government has supported major research efforts on the OCS to document environmental conditions before, during, and after oil and gas exploration, production, and transmission. Among these efforts is the Environmental Assessment of Buccaneer Gas and Oil Field in the Northwestern Gulf of Mexico, a project funded by the Environmental Protection Agency (EPA) through interagency agreement with the National Oceanic and Atomospheric Administration (NOAA) and managed by the National Marine Fisheries Service (NMFS), Southeast Fisheries Center (SEFC), Galveston Laboratory, in Galveston, Texas. Initiated in the autumn of 1975, the study is now in its last year. Its major products have been annual reports disseminated by the National Technical Information Service, data files archived and disseminated by NOAA's Environmental Data and Information Service, and research papers written by participating investigators and published in scientific or technical journals. Results have also been made available through EPA/NOAA/NMFS project reviews and workshops attended by project participants, and various governmental (Federal and State), private, and public user groups. The final products will be milestone reports summarizing the findings of the major investigative components of the study.

Objectives of the project are (1) to identify and document the types and extent of biological, chemical and physical alterations of the marine ecosystem associated with Buccaneer Gas and Oil Field, (2) to determine specific pollutants, their quantity and effects, and (3) to develop the capability to describe and predict fate and effects of Buccaneer Gas and Oil Field contaminants. The project uses historical and new data and includes investigations both in the field and in the laboratory. A brief Pilot Study was conducted in the autumn and winter of 1975-76, followed by an extensive biological/chemical/physical survey in 1976-77 comparing the Buccaneer Gas and Oil Field area with adjacent undeveloped or control areas. In 1977-78, investigations were intensified within Buccaneer Gas and Oil Field, comparing conditions around production platforms, which release various effluents including produced brine, with those around satellite structures (well jackets) which release no effluents. In 1978-79, studies around Buccaneer Gas and Oil Field structures focused on (1) concentrations and effects of pollutants in major components of

the marine ecosystem, including seawater, surficial sediments, suspended particulate matter, fouling community, bacterial community, and fishes and macro-crustaceans, (2) effects of circulation dynamics and hydrography on distribution of pollutants, and (3) mathematical modeling to describe and predict sources, fate and effects of pollutants. The final year, 1979-80, of study is continuing to focus on items (1) and (2) and on preparation of the milestone reports which will represent the final products of this study.

This project has provided a unique opportunity for a multi-year investigation of effects of chronic, low-level contamination of a marine ecosystem associated with gas and oil production in a long-established field. In many respects, it represents a pioneering effort. It has been made possible through the cooporation of government agencies, Shell Oil Company (which owns and operates the field) and various contractors including universities and private companies. It is anticipated that the results of this project will impact in a significant way on future decisions regarding operations of gas and oil fields on the OCS.

Charles W. Caillouet, Project Manager
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INTRODUCTION

Location of Study Area

The area selected for study is the operational Buccaneer Gas and Oil Field located approximately 49.6 kilometers (26.8 nautical miles) south southeast of the Galveston Sea Buoy off Galveston, Texas (Figure 1). This field was selected in 1975 as the study area because: (a) the field had been in production for about 15 years, which time had allowed full development of the associated marine communities; (b) it was isolated from other fields which facilitated the selection of an unaltered area (for comparison) within a reasonable distance of the field; (c) it produced both gas and oil that represented sources of pollutants from marine petroleum extraction; (d) its location simplified logistics and reduced the cost of the research; and (e) the Texas offshore area had not been fully developed for gas and oil production but was expected to experience accelerated exploitation in the future.

Operation History of Buccaneer Field

Buccaneer Field was developed by Shell Oil Company in four offshore blocks leased in 1960 and 1968 as follows:

Year	Lease Number	Block Number	Acreage	Hectares
1960	G0709	288	2,790	1,129
1960	G0713	295	4,770	1,930
1960	G0714	296	4,501	1,821
1968	G1783	289	2,610	1,056

In development of the field, 17 structures were built; two are production platforms, two are quarters platforms, and 13 are satellite structures surrounding well jackets. Initial exploratory drilling began about mid-summer of 1960 with mobile drilling rigs. When (as the result of the exploratory drilling) proper locations for platforms were selected, the permanent production platforms were constructed.

There have been no reports of major oil spills from this field. There have been some reported losses of oil due to occasional mechanical failure of various pieces of equipment. The largest reported spill was three barrels in 1973. The reported oil spill chronology and quantity for Buccaneer Field is as follows:

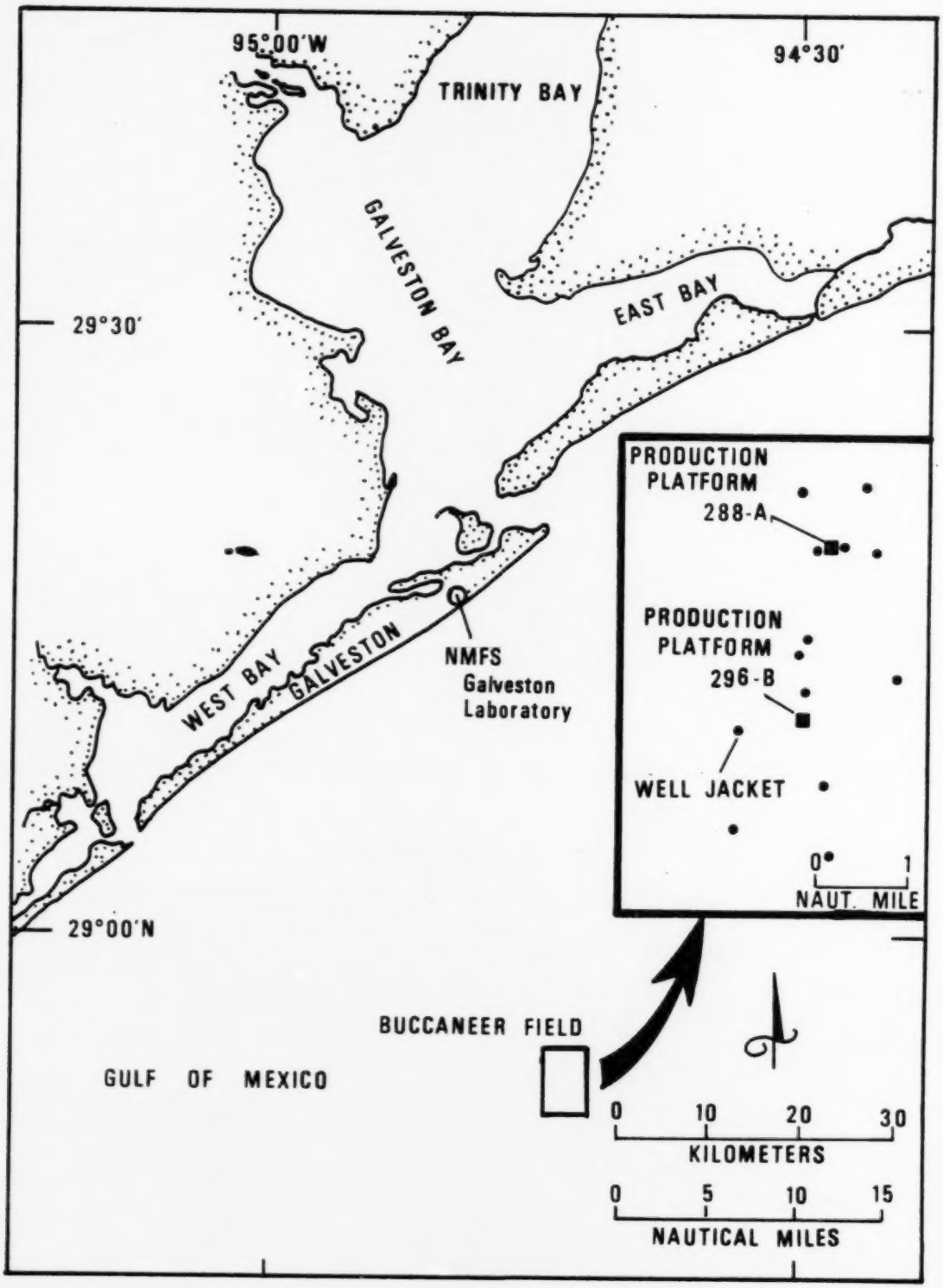

FIGURE 1. LOCATION OF BUCCANEER FIELD

Date	Source	Amount	
		Barrels	Liters
September 1973	Platform 296-B	0.5	79
November 1973	Unknown	3.0	477
July 1974	Platform 296-B	0.5	79
August 1974	Platform 296-B	1.7	265
September 1975	Platform 288-A	0.2-0.4	38-56
Totals		5.9-6.1	938-956

Buccaneer Field first began operations with the production of oil. Later, when significant quantities of gas were found, the field began producing both oil and gas and has continued to do so to date.

The production platforms and satellites (well jackets) are connected by a number of pipelines with a 50.8 centimeters (20-inch) diameter main pipeline connecting the field to shore. All of the pipelines that are 25.4 centimeters (10 inches) or greater in diameter are buried. The Blue Dolphin Pipeline Company was granted a pipeline permit (No. G1381, Blocks 288 and 296) in 1965 and has operated the pipeline since its construction.

Buccaneer Field occupies a limited area (about 59.3 km^2; 22.9 sq. statute miles) leased in the northwestern Gulf of Mexico. Four types of structures are located in Buccaneer Field: production platforms, quarters platforms, satellites (well jackets), and flare stacks. These are shown in Figure 2, which is an oblique aerial photograph of production platform 288-A and vicinity within Buccaneer Field. A map of Buccaneer Field, (Figure 3) depicts the locations of platforms and satellites within the field.

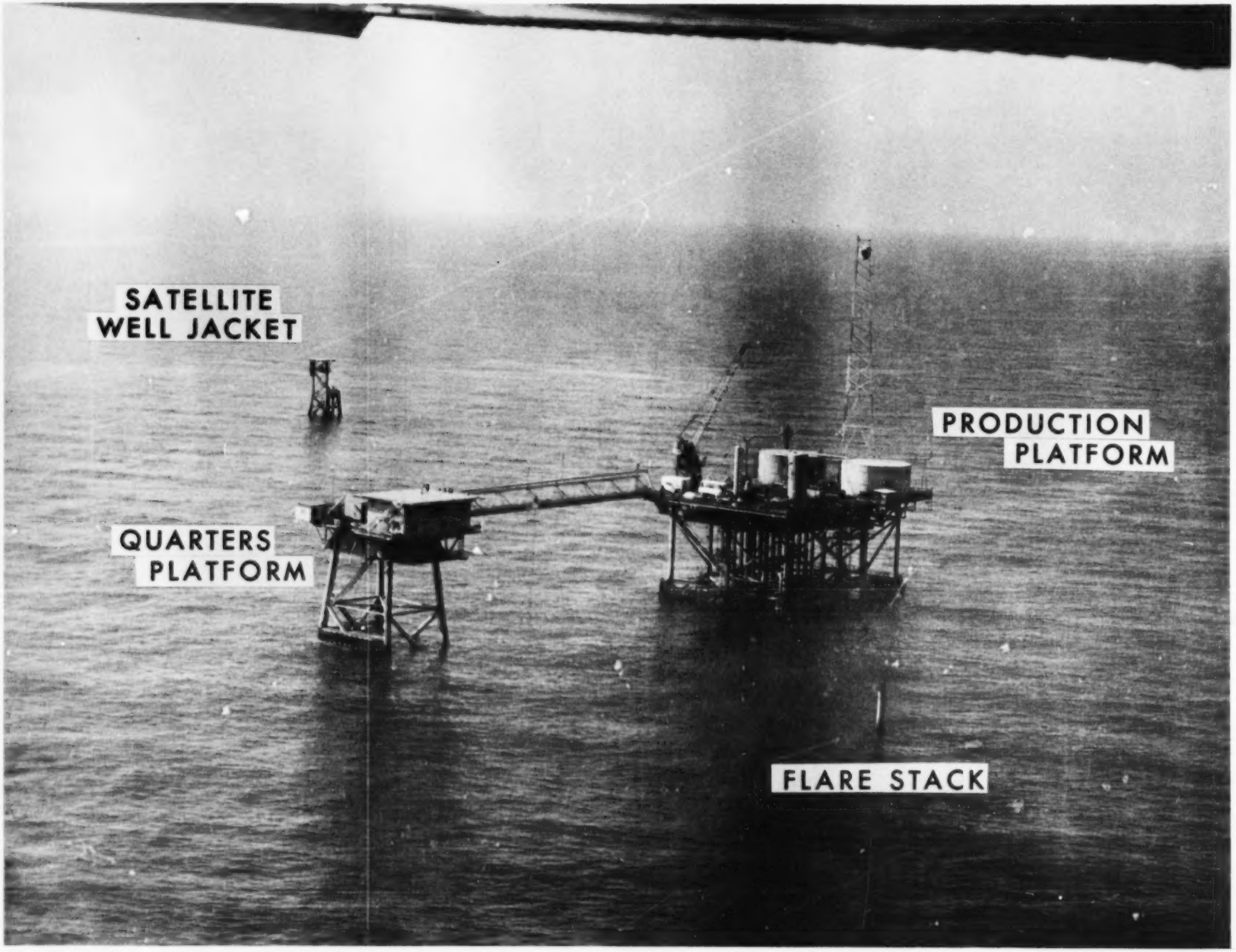

FIGURE 2. BUCCANEER FIELD STRUCTURES

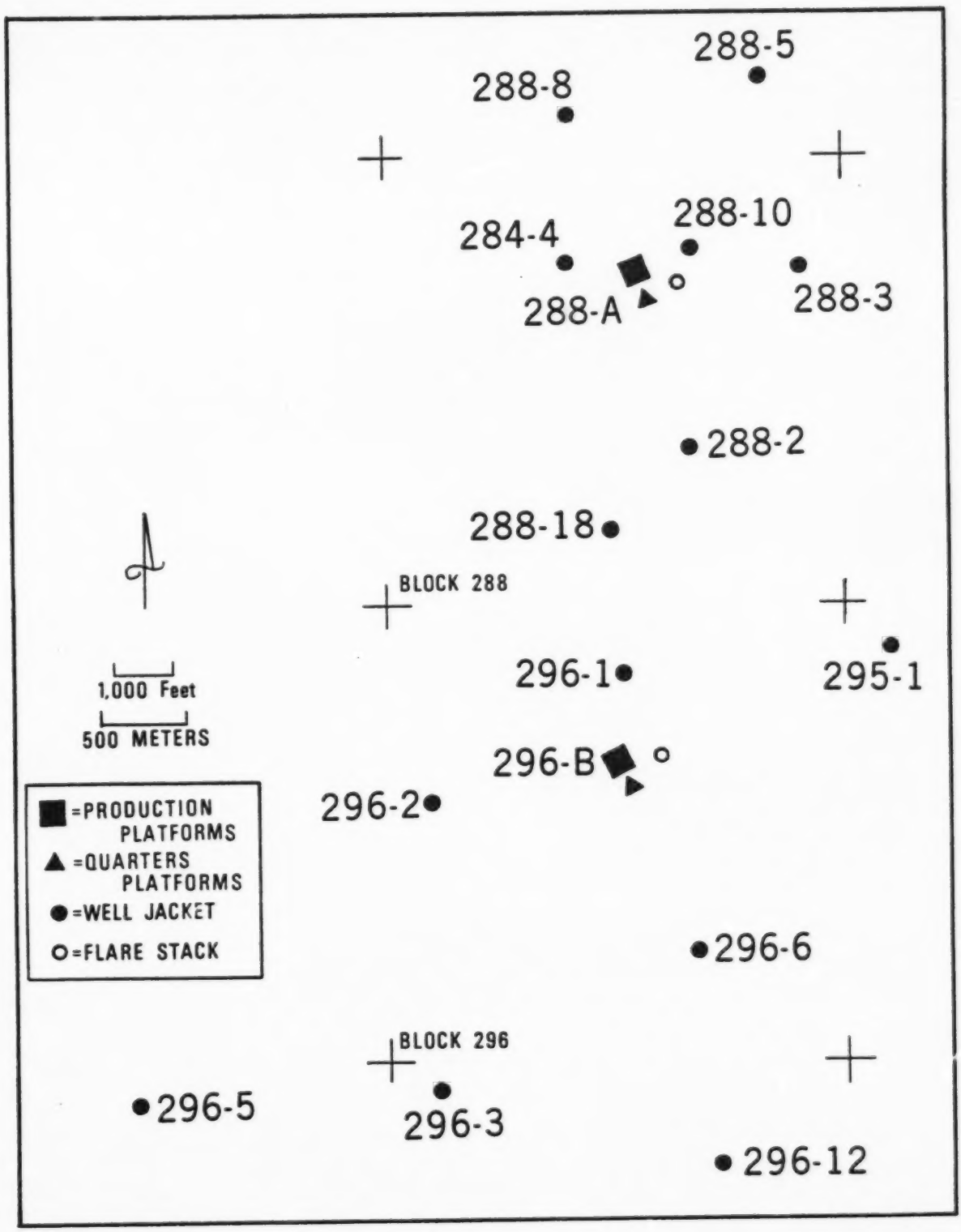

FIGURE 3. SHELL OIL COMPANY'S ALPHANUMERICAL IDENTIFICATION OF BUCCANEER GAS AND OIL FIELD STRUCTURES

WORK UNIT 2.3.9 - CURRENTS AND HYDROGRAPHY OF THE BUCCANEER OIL FIELD AND ADJACENT WATERS

Hazleton Environmental Sciences

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ABSTRACT

Four seasonal hydrographic surveys were conducted in the vicinity of the Buccaneer Oil Field in an effort to describe the physical environment in and around a producing oil and gas field. The measurements that were made included currents, wind, waves, total suspended solids, and hydrographic parameters including temperature, salinity, conductivity, dissolved oxygen, pH, and transmissivity. The results of the study indicated that the area can best be described as a mixing zone for coastal and offshore waters. The mixing of water masses resulted in salinity variations as great as 3.6 ppt across the 6-mile study area. The area is also a high energy regime with considerable scouring from waves and currents but also with a potential for sedimentation during the more quiescent periods. The measured currents frequently exceeded 40 cm/sec and occasionally exceeded 60 cm/sec. The changing currents which are influenced by the tides, winds, and shoreline, continually shift the location of the mixing zone. Consequently the extent of the penetration of the fresh coastal water and therefore the distribution of salinity and temperature are quite variable. This variability in conjunction with the normal seasonal changes results in a variable hydrographic environment.

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INTRODUCTION

Within recent years, a Federal research effort has been initiated to assess the environmental impact of oil and gas exploration and production along the outer continental shelf. In conjunction with this effort, the National Marine Fisheries Service (NMFS) has initiated a comparative environmental assessment of the producing Buccaneer Gas and Oil Field. The study is a multidisciplinary effort of which the Currents and Hydrography Work Unit is one of the 11 separate tasks.

The goal of the Currents and Hydrography Work Unit was to provide a complete description of the existing hydrographic environment in and around the Buccaneer Oil Field. Consequently, seasonal field studies were conducted which include measurement of currents, wind, waves, total suspended solids, and hydrographic parameters including temperature, salinity, conductivity, dissolved oxygen, pH, and transmissivity. The monitoring was conducted in an effort to describe and predict the energy regimes related to suspension, deposition, resuspension, and transport of surficial sediments and other particulate matter.

METHODS AND MATERIALS

Four currents and hydrography cruises were conducted in the Buccaneer Oil Field, Gulf of Mexico, from July 1978 to May 1979. During the first cruise from 25 to 27 July 1978 and the third cruise on 14 February 1979, six types of measurements were made from either the vessel GUS III or from Production Platform B belonging to Shell Oil Company. The measurements included (1) hydrographic sampling consisting of *in situ* measurements of conductivity, salinity, temperature, dissolved oxygen, pH, and transmissivity, (2) electromagnetic current meter measurements, (3) total suspended solids, (4) continuous wind measurements, (5) continuous current meter measurements, and (6) wave measurements. The wind, waves, and continuous current measurements were made for a period of at least 30 days during the first and third field studies. Only hydrographic sampling, total suspended solids and electromagnetic current meter measurements were made during the second cruise (25 to 26 October 1978) and the fourth cruise (8 to 9 May 1979). The methods used in collecting and processing the data were as follows:

Hydrographic Measurements

Conductivity, salinity, temperature, depth, dissolved oxygen (DO), pH and transmissivity were measured at 11 sampling stations within a six nautical mile (11 kilometer) square grid centered on the Buccaneer Field (Figure 1). An InterOcean Model 513D CSTD Probe was used to measure each parameter at approximately 1-sec intervals as the probe was lowered to within 1 m of the bottom. The measurements were relayed to an InterOcean Model 690M Digital Data Recorder which recorded the signals on magnetic tape. The CSTD probe was also linked with an InterOcean Model 514D CSTD Readout unit. This unit provided digital and analog readout

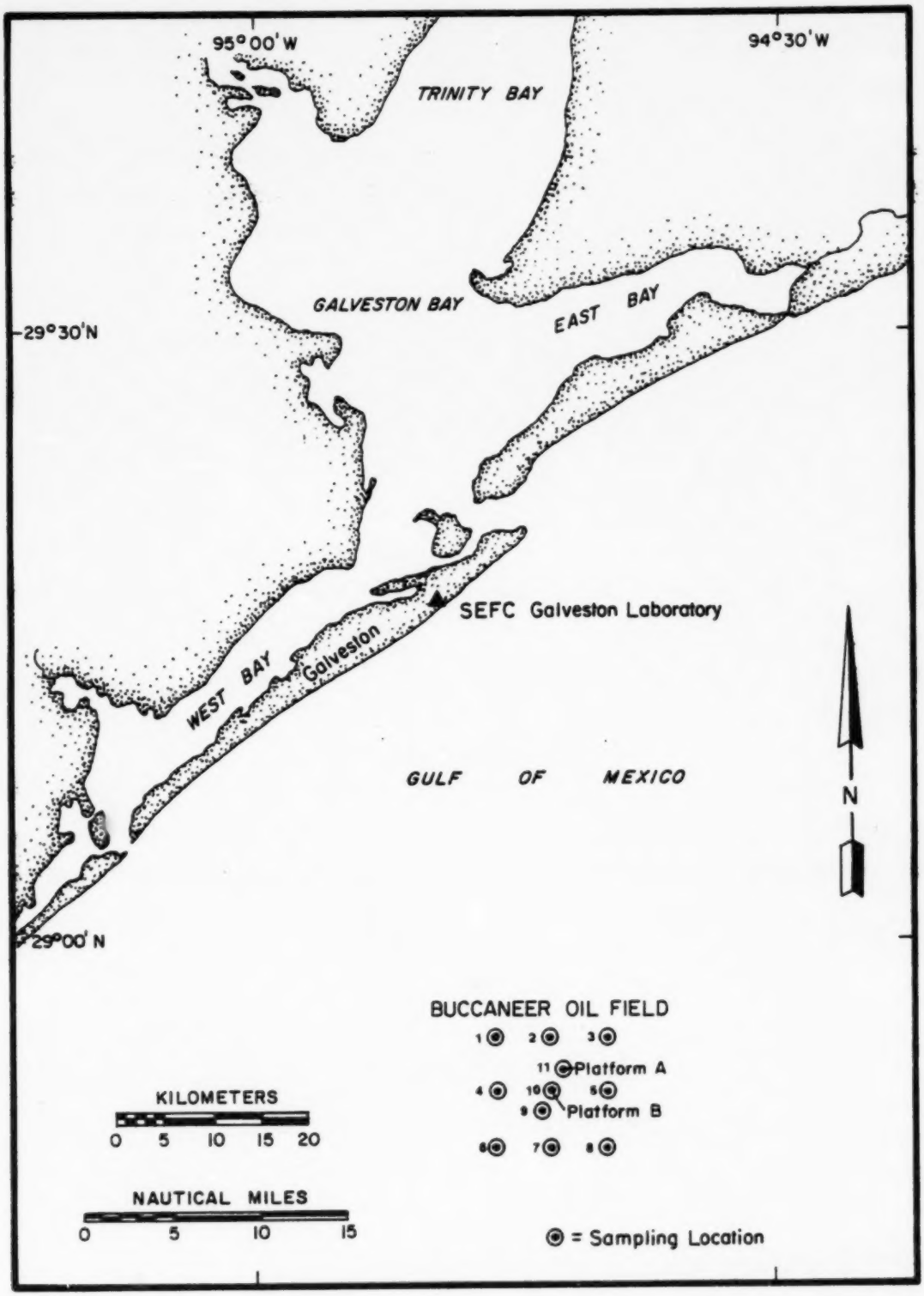

Figure 1. Site location and hydrographic sampling grid for the Currents and Hydrography Study conducted by Hazleton Environmental Sciences in the Buccaneer Oil Field, Gulf of Mexico.

of individual parameters so that the measured signals could be monitored and selected parameters could be manually recorded if desired.

The CSTD data were recorded on magnetic tape as the probe descended. When the probe was within 1 m of the bottom the cassette recorder was turned off. Values of each of the physical parameters were then recorded manually in a log book as a backup. The CSTD was then raised consecutively to depths of 10 and 1.5 m, and the physical parameters at each level were again recorded in the log book. The accuracy, range, and time constants of the probes used on the CSTD are given in Table 1.

Table 1. The accuracy, range, and time constants of the probes on the InterOcean Model 513D CSTD.

Parameter	Range	Accuracy	Time Constant
Conductivity	0-65 millimhos/cm	± 0.05	10 ms
Salinity	0-40 ppt	± 0.05	1.4 sec
Temperature	-5-45°C	± 0.05	60 ms
Depth	0-200 m	± 1	50 ms
Dissolved Oxygen	0-40 ppm	± 0.2	10 sec
pH	2-14 pH	± 0.1	200 ms
Transmissivity	0-100 %	± 1	400 ms

To insure the accuracy of the collected data all of the probes were calibrated annually by the manufacturer. In addition, the pH, DO, conductivity and transmissivity probes were calibrated in the field against known standards. The results of the field calibrations were then used during data processing to adjust the recorded data.

Tables and vertical and horizontal contour plots of salinity, temperature, DO, pH and transmissivity were computer generated from the data collected at the 11 stations to aid in the interpretation of the results. Some of these are presented in this report to help illustrate the hydrographic features of the area.

Total Suspended Solids

Water samples for total suspended solids were collected with a Jabsco Model No. 36600-0030 water pump rated at 8 gallons per minute. A graduated weighted plastic intake line was lowered to several depths from which the samples were pumped. Sufficient time was allowed to flush the intake tube before the water sample was collected in a rinsed glass bottle. The sample was then labeled and refrigerated until it was analyzed.

The technique for analyzing the water samples was that described in "Standard Methods for the Examination of Water and Wastewater", Fourteenth Edition (Taras 1975). Briefly the method is as follows: A Reeve-Angel Glass Fiber Filter (Grade No. 934-AH) is placed in a Gooch crucible, the apparatus is rinsed with distilled water, dried at 105°C and the tare weight of the apparatus is obtained. A 500 ml aliquot of well mixed sample is filtered under vacuum, then the apparatus is again dried at 105°C and reweighed. This weight minus the tare weight times 2 yields the total suspended solids value in mg/l. These data were then tabulated for presentation and comparison.

Current Meter Measurements

Vertical profiles of the currents were taken during the ebb and flood stages of the tide at 6 or more stations near Platform B with a Marsh-McBirney Model 727 Electromagnetic Current Meter. Currents were normally measured at depths of 2 m, 5 m, 10 m, and 15 through 19 m, at 1-m intervals. The time, orientation of the probe, and x and y velocity components were recorded on field data logs. These data were then keypunched and loaded on to a DEC-10 computer system which then produced vertical profile plots of the currents to aid in interpretation of the data.

The current meter has a stated threshold velocity of 0.5 cm/sec, which is also the resolution of the recorded velocity components. Absolute accuracy of the measurements is specified as being $\pm$ 2 percent of the instrument readout. Maximum long-term drift, an inherent instrument error, is approximately 1.9 cm/sec. Consequently, under worst case conditions of large zero-drift, the measurements could be in error by as much as 2 cm/sec. Additional error can be induced into the measurements if there is substantial vertical movement of the instrument such as that induced by wave action on the boat.

Continuous current measurements were made at one station approximately 45 meters south of the Quarters Section of Platform B with a three meter multidepth array using ENDECO Type 105 Current Meters. The ENDECO Type 105 Current Meter is an axial flow, ducted impeller instrument. Analog values of impeller rotation, magnetic bearing of the instrument and a 24-hour mark comprise the data that are recorded on the 16-mm film. Each meter was calibrated by ENDECO just prior to the study. Direction calibrations were made by comparing indicated directions with real magnetic headings every 15 degrees of swing. Speed calibrations were conducted using a synchronous motor attached to the tailshaft. The threshold speed for the impeller is 2.5 cm/sec with a resolution of 2.5 cm/sec and an accuracy of $\pm$ 3 percent of full scale. Current direction accuracy is $\pm$ 5° at threshold speed, $\pm$ 3.6° above threshold speed, and is resolvable to $\pm$ 3.6°.

One meter for each depth was placed at 4.5, 10.5 and 18 meters below the surface. The bottom current meter was approximately 2 meters above the sea floor. The mooring was anchored with a 200 kg weight and the mooring line was supported by a subsurface float. A 60 meter ground line ran from the 200 kg weight to the leg of Platform B to facilitate retrieval of the array.

Following retrieval of the instruments, the data films were sent to ENDECO for processing. The processed data consisting of speed and direction values for each 30-minute interval during the recording period were entered onto the computer system. Tables of current speed and direction, joint frequency distribution tables, progressive vector plots, and current speed and direction plots were generated from the data.

Meteorological Measurements

Meteorological data were collected continuously for approximately 30 days during the first and third field studies with a Meteorology Research Incorporated Model 1071 Mechanical Weather Station. This device was mounted 30 meters above the sea surface on Platform B. Analog values of wind run and wind direction were continuously recorded. The threshold of the instrument was 0.34 m/sec for both the vane and the cup anemometer. The speed was recorded with an accuracy of $\pm$ 2 percent of the measured value and the direction with an accuracy of $\pm$ 3.6° and a resolution of 15°.

The data were returned to the laboratory and converted to hourly average values from the analog record. The results were then entered into the computer data base. Tables of wind speed and direction, joint frequency distribution tables, and progressive vector plots were then generated from the data.

Periodic meteorological observations were made from aboard the vessel GUS III during the study to supplement the continuous observations recorded on Platform B. Wind speed was measured using a hand held Dwyer Wind Gauge and the wind direction was determined from a magnetic compass and corrected to degrees from true north. Wet bulb and dry bulb temperatures were measured with a Bendix psychrometer. Cloud cover, wave height and wave direction were estimated from visual observations.

Wave Measurement

Wave measurements were made with a Bass Engineering Model WG/100M self-contained wave measuring and recording system that was installed in approximately 5 m of water on Well Jacket SHGA288-18. The instrument sensed pressure fluctuations with a Bourdon tube pressure transducer whose signal was transformed with an optical lever system to produce a variable voltage output. The operation of the optical lever system is described in detail by Bass and Byrnes (1974). This system determined water surface variations with a precision of $\pm$ 6 mm and a resolution of $\pm$ 3 mm. The timing was controlled by a crystal clock that had an accuracy of $\pm$ 0.01 percent. The wave field was sampled every 4 hours for a 9.6-min interval during which time water height measurements were taken every 1.0 sec. The data were recorded on a magnetic cassette that was later decoded and entered onto the computer system.

The data were first automatically scanned to remove all bad characters from the data and also to check for the proper timing sequence that precedes each data set. The resulting data sets were then detrended and the mean was subtracted, which left only the pressure fluctuations about

a zero mean. The residual pressure readings were subsequently plotted and examined visually to remove any outlying points. All erroneous points were replaced by a linear interpolation of the two adjacent points. The clean data sets obtained after the editing process were used for subsequent analyses.

The consecutive zero-up-crossing method was used to analyze the wave data. This method defined the point where the water-level signal changed from negative to positive as the beginning of a wave and the next zero-up-crossing as the end of the wave. Each wave height was determined by calculating the difference between the maximum and minimum water level values between consecutive zero-up-crossings, and the wave period was simply the time interval between up-crossings. The entire data set for each 9.6 min recording interval was analyzed in this manner and, typically, 100 waves were tabulated. These waves were then sorted according to wave height and the highest one-third were averaged to determine the significant wave height for that recording interval. The periods of the highest one-third waves were then averaged to determine the significant wave period.

Since the wave gauge was located 5 m below the surface and since the pressure signals from water-level fluctuations decrease with depth in the water column, the measured wave height values were corrected to estimate the actual wave heights at the water surface. The corrections for this attenuation of the pressure fluctuations with depth were made as described by Kim and Simons (1974). The wave height at the surface H is related to the measured wave at depth H_z by the equation:

$$H = \frac{\cosh (KD)}{\cosh K(D-Z)} \quad H_z \qquad (1)$$

where: D = total water depth
K = wave number
Z = depth of the sensor

The wave number was determined implicitly from the dispersion equation:

$$\omega^2 = gK \tanh (KD) \qquad (2)$$

where ω = wave frequency = 2π/period
g = acceleration due to gravity

The procedure followed was to first determine H_z from the zero-up-crossing method and then compute H from Equation 1. Equation 2 was used to calculate K, which used the wave period determined from the zero-up-crossing routine. An estimation of the maximum value of the elliptical velocity of the wave field at the bottom was then made by using a variation of Equation 1 to compute the theoretical amplitude of the motion at the bottom, H_b. The amplitude of the elliptical velocities were then estimated according to;

$$\text{Orbital Velocity (OV)} = \frac{1}{2}\omega H_b = \pi H_b/\text{Period} \qquad (3)$$

A similar method for computing orbital velocities is described in detail by Kinsman (1965).

The final result of the wave record analysis was a tabulation of significant wave height, wave period, and OV estimations near the bottom recorded every 4 hr while the instrument was in operation.

RESULTS AND DISCUSSION

The results of the data collected during the 4 cruises (25-27 July and 25-26 October 1978 and 14 February and 8-9 May 1979) are presented in the following section. The order of presentation is as follows: hydrography (including salinity, temperature, dissolved oxygen, pH, and transmissivity), currents, total suspended solids, and wind and waves. A summary of the parameters that were collected during each cruise and the number of stations, sampled is presented in Table 2.

Table 2. Data collection summary indicating data type, cruise, and number of stations for each data type.

	July 1978	October 1978	February 1979	May 1979
Hydrography				
Conductivity	11	11	11	11
Salinity	11	11	11	11
Temperature	11	11	11	11
Dissolved Oxygen	11	11	11	11
pH	11	11	0	11
Transmissivity	11	11	11	11
Total Suspended Solids	2	2	2	2
Current Measurements				
Continuous	1	-	1	-
Electromagnetic	7	6	7	6
Wave Measurements	1	-	1	-
Meteorology Measurements				
Continuous	1	-	1	-
Shipboard	11	11	11	11

Hydrography

The salinity in the area surrounding the Buccaneer Oil Field generally increased to the south (Figure 2). This trend has been reported by Capurro and Reid (1972) and is attributed to freshwater runoff from the land surrounding the Gulf of Mexico (Capurro and Reid 1972, Temple et al. 1977, and U.S. Dept. of Commerce 1977). Most of this freshwater flows west and may freshen the Gulf of Mexico as far south as the Mexican border. An exception to this general salinity distribution pattern was observed during July 1978 as the water was more saline to the north. This reversal in the salinity gradient was probably caused by local cur-

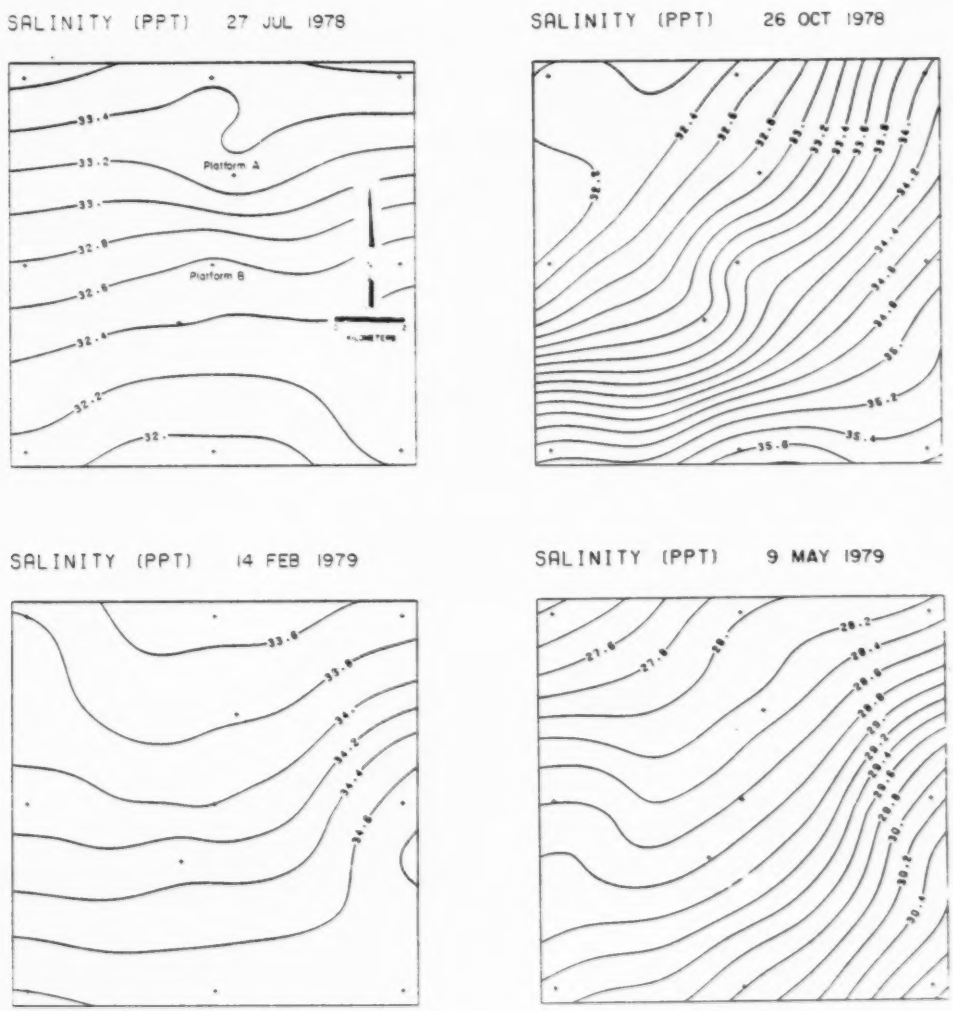

Figure 2. Horizontal contour plots of surface salinity in the Buccaneer Oil Field for July and October 1978 and February and May 1979. The units are parts per thousand.

rents altering the salinity distribution as previous observations indicate that the currents in July are generally to the northeast rather than the predominant southwesterly direction (U.S. Dept. of Commerce 1979).

Although the salinity trends for October 1978, February 1979, and May 1979 all revealed an increase in salinity to the south, the magnitude of the salinity gradient and the average salinity varied from seasor to season. During October, the surface salinity ranged from 32.2 parts per thousand (ppt) in the north to 35.6 ppt in the south which is an increase of 3.4 ppt across 6 nautical miles (11 kilometers). Not only was the salinity gradient reversed in July 1978, but the magnitude of the gradient was only one third as large as the salinity gradient observed in October. The July salinities ranged from 32.0 ppt in the south to 33.4 ppt in the north.

The surface salinity in February 1979, during the low runoff period, ranged from 33.5 ppt in the north to 34.8 ppt in the south. However, the May 1979 salinity, during the high runoff period, ranged from 27.2 ppt in the north to 30.9 ppt in the south. The average surface salinity in May of 29.0 ppt was well below the February average salinity of 34.2 ppt. In fact, the May 1979 average surface salinity was approximately 4 to 5 ppt lower than the average surface salinities determined from the July and October 1978 and February 1979 sampling periods. This 4 to 5 ppt decrease in surface salinity has been reported for the month of May by Temple et al. (1977) and was attributed to increased runoff just prior to, and during, the month of May. Temple also reported that these marked decreases in salinity were related to peak outflow from the Mississippi River, but with a time lag of 1 to 2 months. This is quite plausible as the coastal freshwater generally flows west along the Gulf Coast (Capurro and Reid 1972). This report is substantiated by various studies which indicate that the currents generally flow in a westward direction (U.S. Dept. of Commerce 1973 and SEADOCK 1975). These currents would have the tendency to force the freshwater to closely follow the shoreline which would also explain the rather large salinity gradients observed across the 11 kilometer study area.

Vertical cross sections through the middle of the study area (from Station 2 south to Station 7) shown in Figure 3 revealed varied salinity distributions. The July 1978 salinity contours were apparently disrupted by local currents which caused the reverse trend in the horizontal salinity gradient. The northeasterly currents also produced a confluence of water masses at the site as the fresh surface water from the south mixed with the more saline bottom water from the north.

During October 1978 the fresher water wedge intruding from the north basically affected only the top 4 m of water. This was not the case during the winter (February 1979) as there was very little vertical stratification of salinity. The salinity, however, did increase to the south throughout the water column. Intense vertical stratification was evident at the depth interval from 8 m to the bottom during May 1979. The salinity ranged from 27.2 ppt at the surface to 34.0 ppt near the bottom.

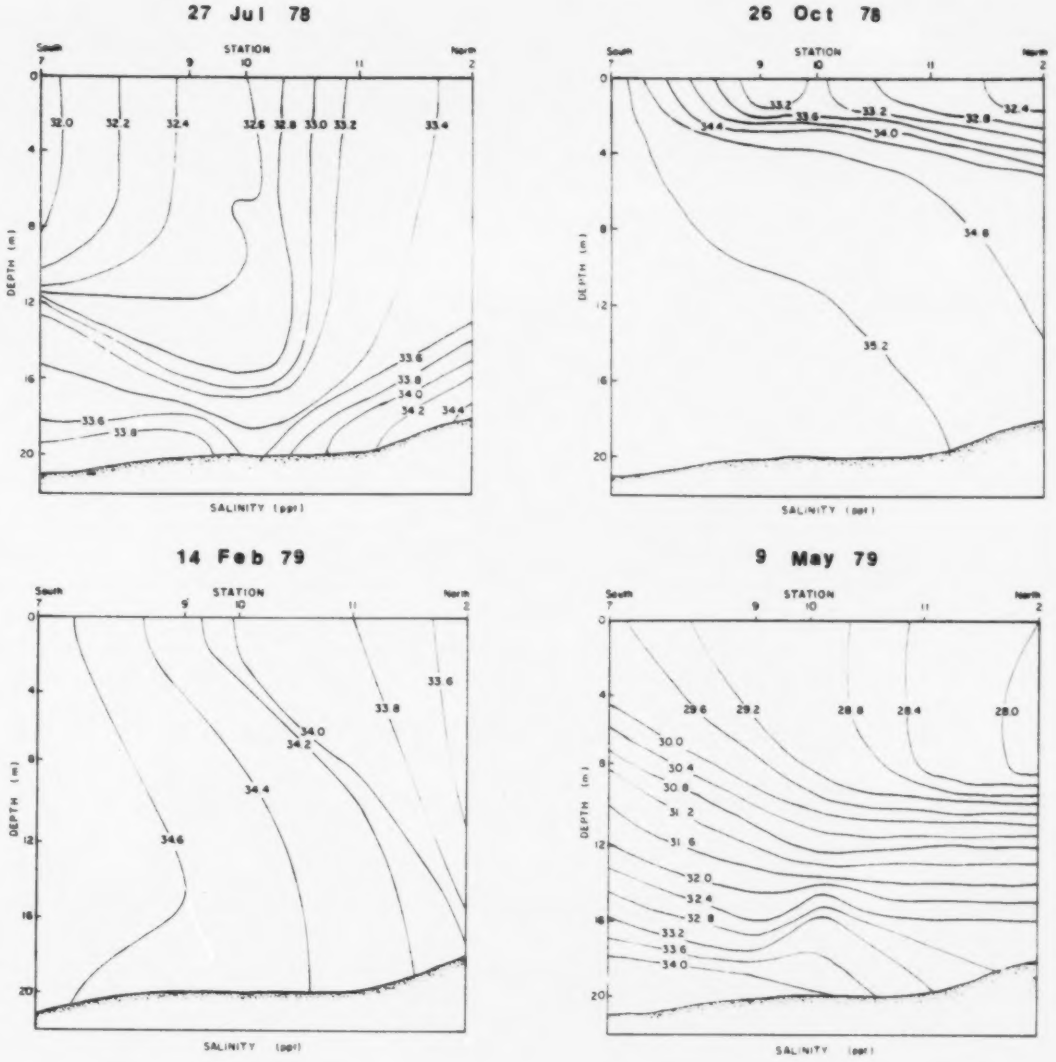

Figure 3. Vertical contour plots of salinity of a north-south cross section through the middle of the Buccaneer Oil Field for July and October 1978 and February and May 1979. The units are parts per thousand.

Generally, the bottom waters did not vary in salinity seasonally as much as the surface waters. This observation was also made by Temple et al. (1977) who reported average bottom salinities of between 33.0 and 35.0 ppt. This was very nearly the range observed by HES during the 4 sampling periods.

The surface temperature distributions were far more complex than the observed salinity patterns as illustrated in Figure 4. The north-south trends so evident with salinity, and the result of freshwater runoff from the land, were nearly non-existent at the surface. However, a weak trend of decreasing temperature toward the north was observed at mid-depth and near-bottom for July and October 1978 and February 1979. This latitudinal variation has been reported by Capurro and Reid (1972) and Temple et al. (1977). The only time this trend was distinct near the surface was during October 1978 when temperatures generally decreased from 24.7°C in the south to 23.8°C in the northwest. The largest surface temperature gradients were observed in February 1979 and were probably the result of cold water runoff from land during the winter months.

The surface temperatures also showed the effects of seasonal cooling as the average temperature of 24.2°C in October was approximately 5.5°C cooler than the surface temperatures in July 1978. The average surface temperature in July of 29.5°C was 0.5°C above the historical average temperature for July (U.S. Dept. of Commmerce 1973). The average surface temperatures in October 1978 (24.2°C) and February (13.7°C) and May 1979 (23.2°C) were below the historical average surface temperatures of 27.0, 18.4, and 24.5°C, respectively (U.S. Dept. of Commerce 1973). However, none of these temperatures were below the reported minimum temperature for their respective months.

It should be noted that the average temperatures calculated for the 4 cruises were each based on a single day's observations, and that due to the nonsynoptic nature of the survey (usually 10 hours) some diurnal warming and cooling in the surface water may have occurred.

The vertical cross sections running north to south through the Buccaneer Oil Field revealed varied temperature distributions (Figure 5). During the July 1978 cruise the temperature was nearly constant throughout the water. A slight temperature inversion (approximately 0.3°C warmer at the bottom) was evident during October 1978. Temperature inversions for the top 20 m of water are normal for the months of January, February, and November according to the U.S. Dept. of Commerce (1973). The apparent instability (due to temperature) of the water column in October was offset by a very fresh layer of less dense surface water.

The temperature during February 1979 generally decreased with depth especially in the southern part of this study area. There was apparently an intrusion of warmer surface water entering the study area from the southeast. During May 1979 the vertical distribution of temperature was much more complex. A fresher, colder (yet less dense) layer of water intruded from the north over the top of warmer more saline water. This resulted in the vertical temperature distribution near Platform A of warm

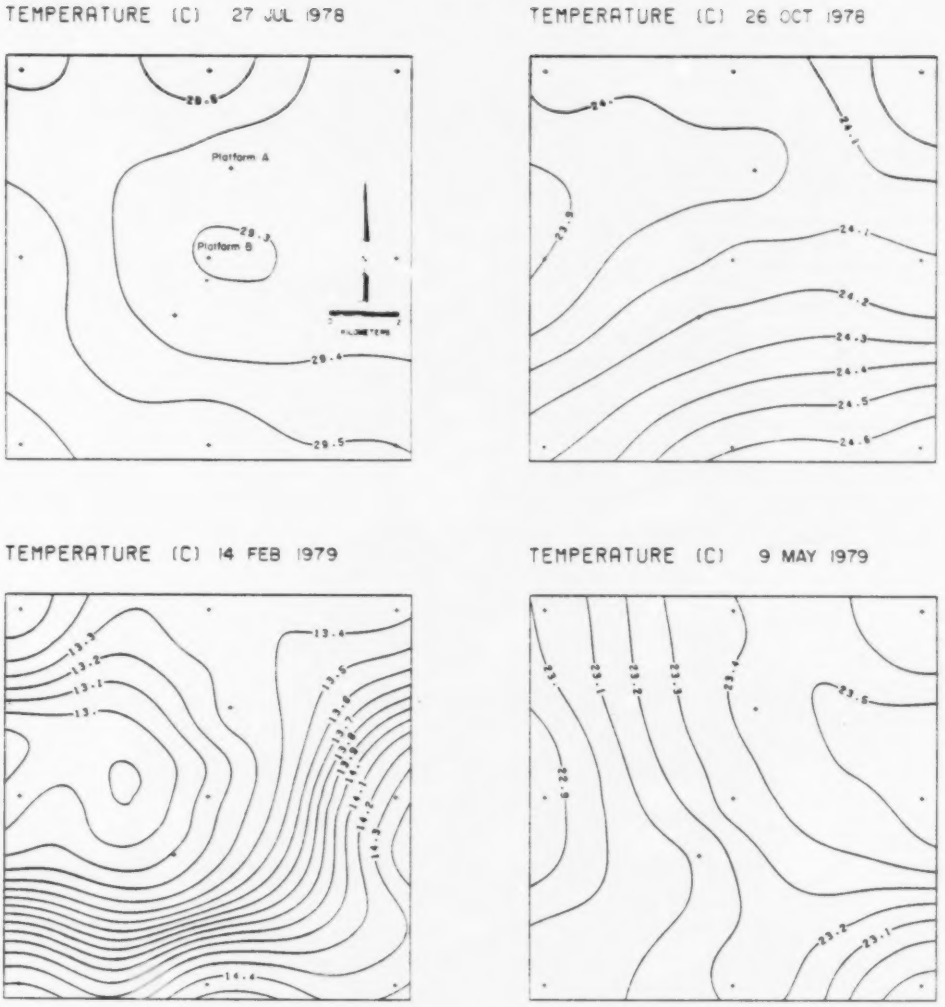

Figure 4. Horizontal contour plots of surface temperature in the Buccaneer Oil Field for July and October 1978 and February and May 1979. The units are degrees Celsius.

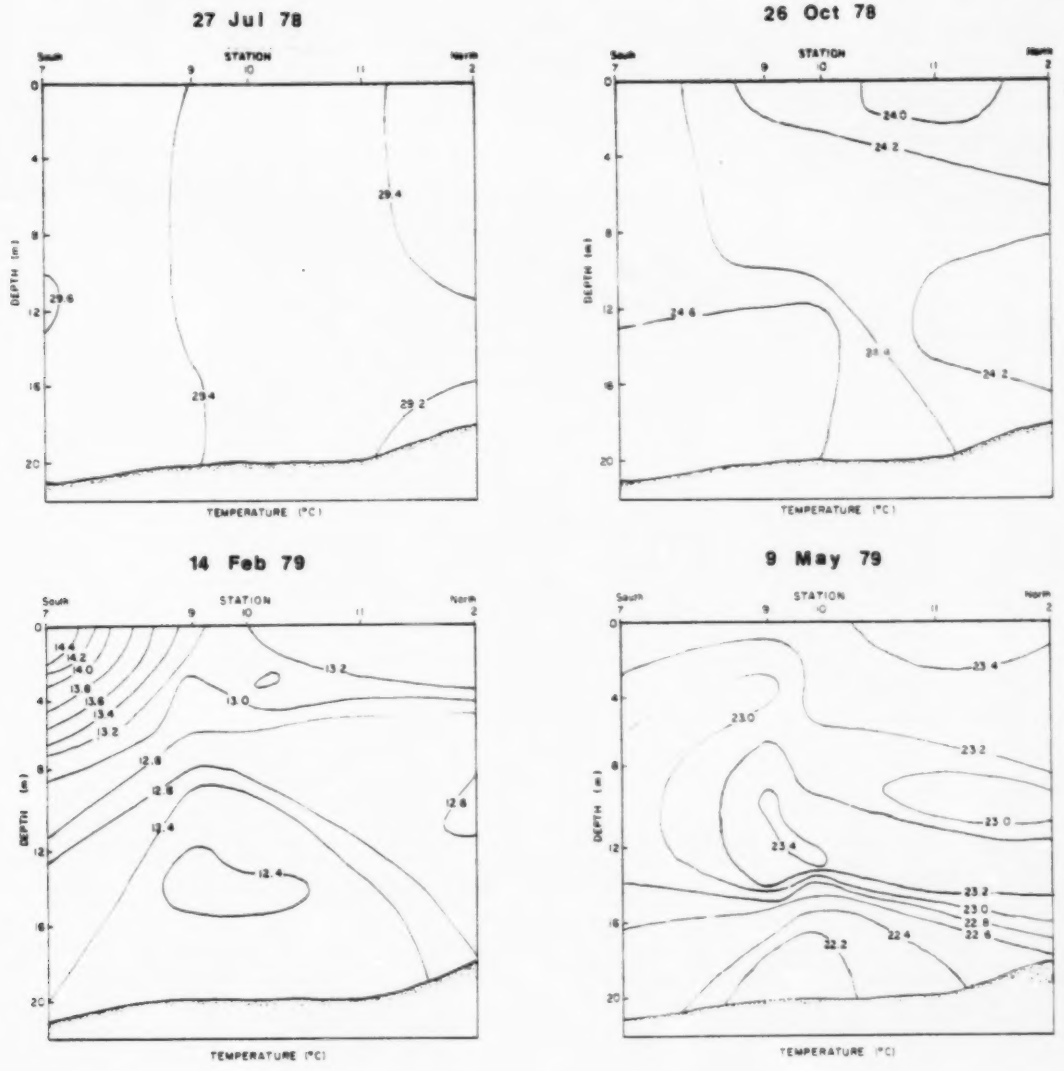

Figure 5. Vertical contour plots of temperature of a north-south cross section through the middle of the Buccaneer Oil Field for July and October 1978 and February and May 1979. The units are degrees Celsius.

surface waters (23.4°C) which decreased to 23.0°C at 9 m; the temperature then increased to near surface temperatures at 13 m before dropping to 22.4°C near the bottom.

The dissolved oxygen (DO) concentrations in the Buccaneer Oil Field generally ranged from 4.0 to 6.0 mg/l. The exception to this occurred in February 1979 when water temperatures of approximately 13°C were at least 10°C cooler than the temperatures measured during the other 3 cruises. These lower temperatures resulted in DO concentrations ranging from 8.1 to 9.1 mg/l. Because of the numerous factors which affect DO concentration, such as temperature, salinity, biological activity, and aeration by waves, no obvious trends in the horizontal and vertical distribution of DO were apparent. Frequently the DO distribution would follow that of the temperature distribution (i.e. decreasing temperatures and increasing DO), but not always. An exception, for example, occurred in May 1979 when the measurements indicated an oxygen depleted layer of cool water near the bottom. The oxygen saturation values on this day varied from about 87% near the surface to about 52% near the bottom. An oxygen depleted layer near the bottom is fairly common and is usually attributed to increased oxidation of detrital material that collects in the nepheloid layer near the bottom.

The pH in the Buccaneer Oil Field ranged from 8.0 to 8.3 for all seasons. There were no discernible trends except for a 0.2 unit decrease from surface to bottom during the May 1979 cruise. The pH distribution could generally be described as seasonally constant and nearly homogeneous both horizontally and vertically.

The water in the Buccaneer Oil Field was typically quite clear as evidenced by the high transmissivity values (never lower than 84% relative to 100% in distilled water). There were no obvious trends in transmissivity other than a general decrease in transmissivity with depth. This decrease was usually no more than 10%. The only exception to this vertical trend occurred in May 1979 when at several stations the water nearest the bottom showed a noticeable decrease in transmissivity and a DO concentration 1.5 to 2.5 mg/l lower than the surface layer. The decreased transmissivity near the bottom was also noticed in the TSS measurements as the values increased from an average of about 3.6 mg/l at a depth of 15 m to about 5.6 mg/l at 18 m. During this period there was also a clearer layer of water sandwiched between the turbid surface layer of water influenced by runoff and the turbid layer of oxygen depleted bottom water. This clear layer of water (2 to 3% more transparent) was also delineated by the vertical temperature and salinity distributions on 9 May 1979. The currents on this day and the preceding evening were generally toward the west-southwest with an average speed of nearly 60 cm/sec. These fast currents apparently resuspended the sediments near the bottom. The migration of material, however, was limited to 3 or 4 m from the water-sediment interface by a weak thermocline that was present at a depth of about 16 m. It is probable that the oxidation of organic material that was resuspended with the sediments produced the low DO values that were observed near the bottom. A vertical profile plot of the temperature, salinity, DO, and transmissivity

that were measured 3 miles west of Platform B and at Platform B is presented in Figure 6 to illustrate the relationship between these parameters.

Currents

Previous studies of currents in the Gulf of Mexico indicate that the nearshore currents along the coast of Texas are predominantly to the west and south with a reversal in May through August with flows to the northeast (U.S. Department of Energy 1978, U.S. Department of Commerce 1979). The general seasonal circulation patterns for the area of the Buccaneer Oil Field are given in Figure 7 (from SEADOCK 1975). These circulation patterns, however, should only be considered as general indications of the expected currents as the actual direction of flow is quite variable (U.S. Department of Commerce 1973). The currents are influenced not only by the large scale circulation in the Gulf, but also by regular tidal changes, changes in the wind, river discharges, density gradients, and meanders from deep water currents, all of which create a variable current system. The vertical variation of the currents in the area also seems variable and unpredictable (U.S. Department of Energy 1978) with frequent reversals in flow within various density layers throughout the water column. Drift buoy measurements in the area in 1976, however, indicated that there was very little vertical variation in the currents (U.S. Dept. of Commerce 1979); simultaneous measurements with current meters on Platform A, though, indicated that there were periods of layering with contrasting directions of flow. Such discrepancies in results indicate that either the water currents in the area are highly variable or the current meter measurements may have been influenced by the proximity of the platform.

The average current speeds that have been reported for the area generally ranged from about 10 to 30 cm/sec. The maximum speeds measured in the general area ranged from 53 cm/sec (U.S. Dept. of Energy 1978) to 180 cm/sec (U.S. Dept. of Commerce 1979) with speeds much farther offshore reaching in excess of 250 cm/sec (U.S. Dept. of Commerce 1973). Spectral analysis of current meter data (U.S. Dept of Commerce 1979) indicated that the semi-diurnal and diurnal tidal frequencies were the major periodic components of the velocity field. Other energy concentrations were observed at periods of 5 and 10.5 days.

The water current observations that were made during the 1978-1979 studies by Hazleton Environmental Sciences generally agreed with many of the previous observations; however, there were also several discrepancies in the results. Progressive vector plots (PROVECS) of the current meter data from 26 July to 30 August 1978 (Figure 8) indicated that the net drift during this period was to the southwest at all depths. Most previous studies had indicated that the flow was to the northeast during this season. The PROVECS also indicated that the direction of flow was quite uniform with depth, which disagrees with previous observations that reported frequent periods of layered flows during the summer (U.S. Dept. of Commerce 1979). The average current speeds varied

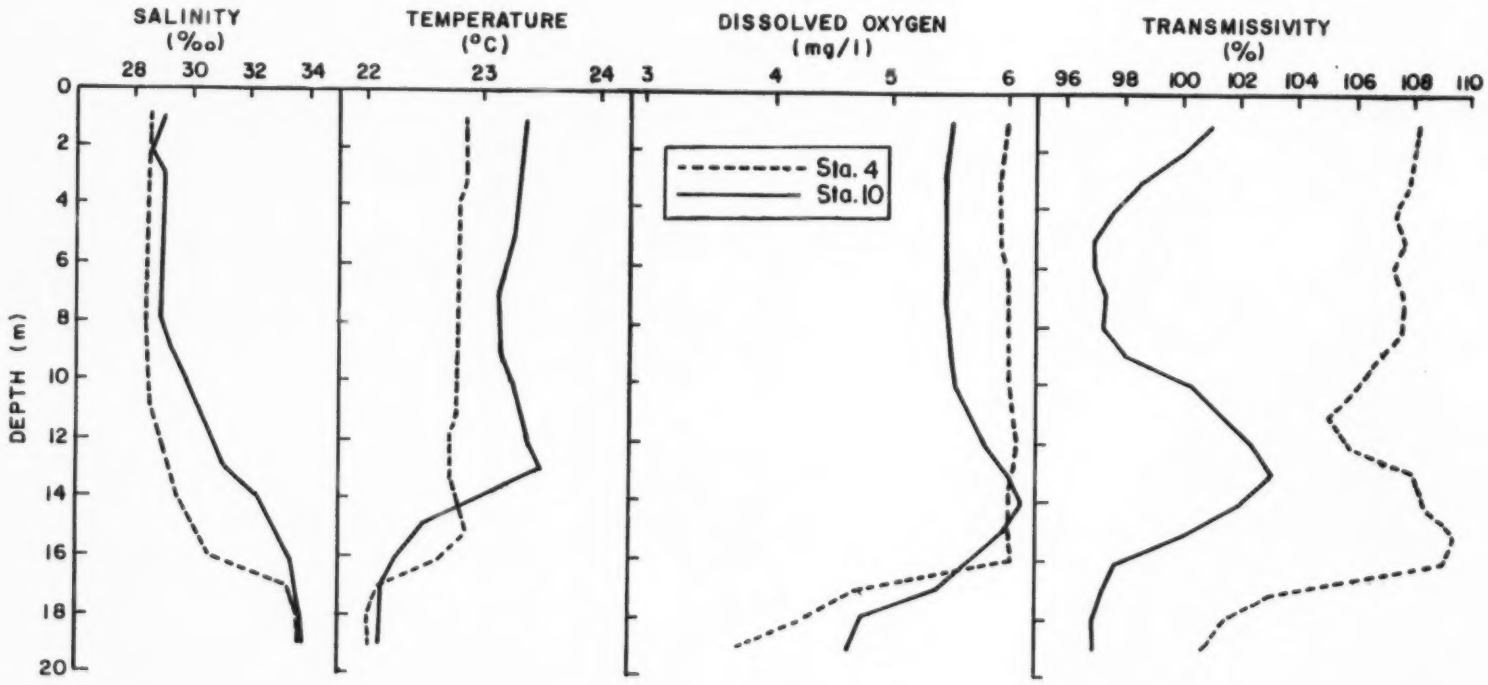

Figure 6. Vertical profile plots of salinity, temperature, dissolved oxygen, and transmissivity for Stations 4 and 10 on 9 May 1979 in the Gulf of Mexico.

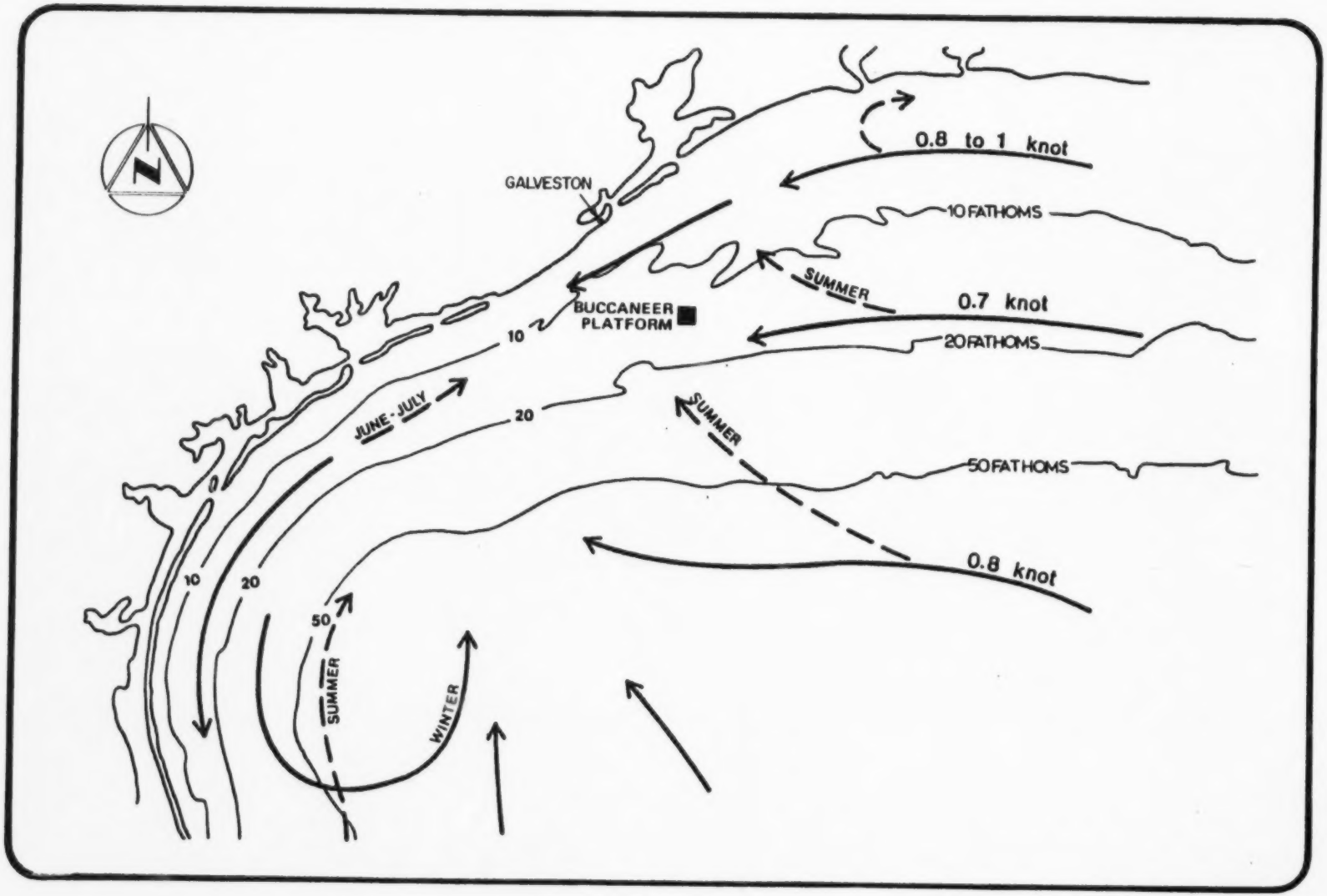

Figure 7. The general seasonal circulation patterns in the vicinity of the Buccaneer Oil Field, Gulf of Mexico (after SEADOCK 1975).

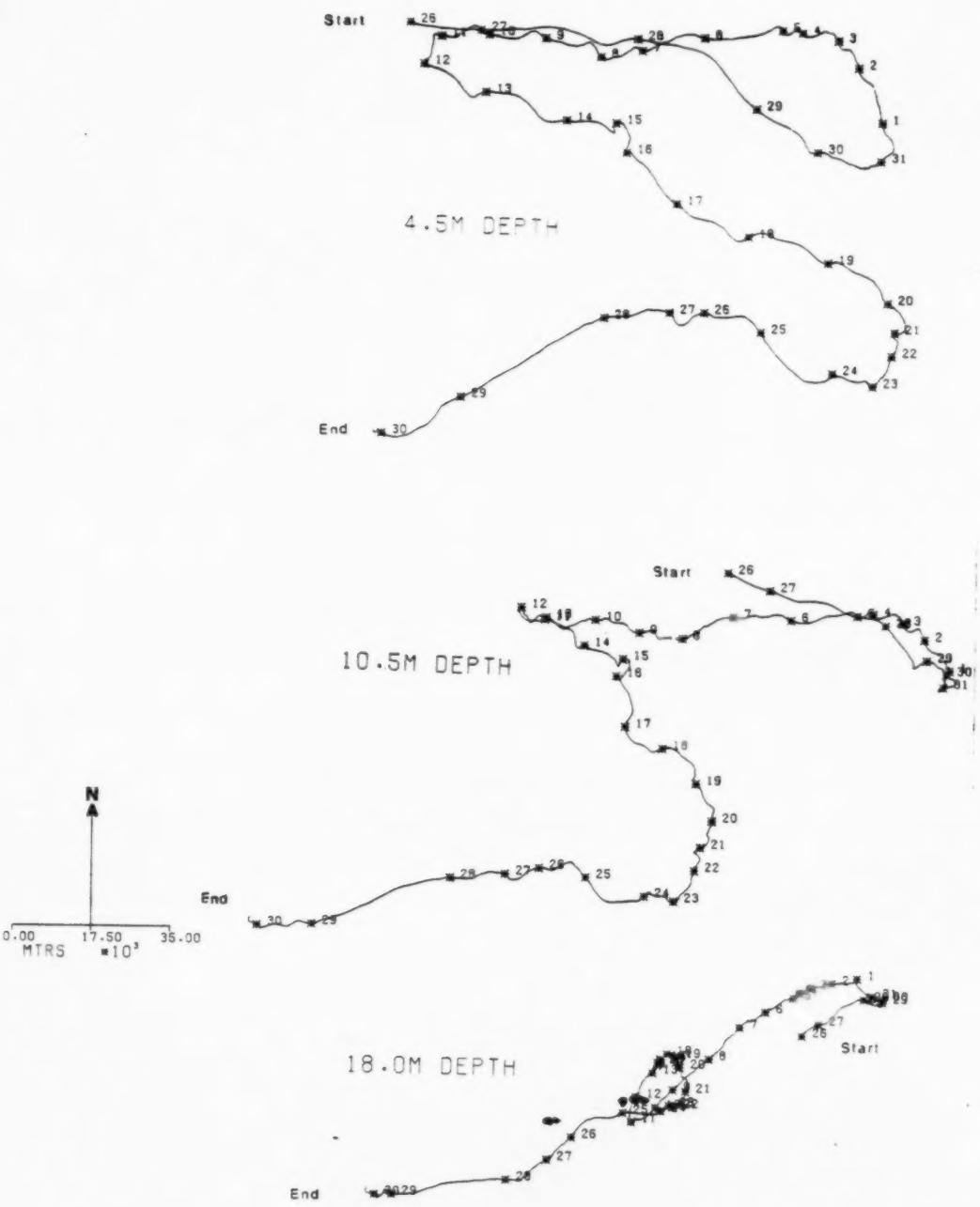

Figure 8. Progressive vector plots of the currents at 3 depths in the Buccaneer Oil Field, Gulf of Mexico, from 26 July to 30 August 1978.

from 18 cm/sec near the surface to 7.7 cm/sec near the bottom. The maximum recorded speed during the July-August recording period was 66.0 cm/sec which occurred on 28 August during tropical storm Debra. The current speed near the bottom exceeded 26 cm/sec more than 2% of the time; this speed is sufficient to resuspend and transport some of the unconsolidated sediments in the area. The maximum speed that was measured near the bottom was 46 cm/sec during tropical storm Debra.

Even though the net flow was to the southwest during the 1978 sampling period, the PROVECS illustrated the large variations in the current direction. The currents generally followed an east-west orientation in flow with reversals in flow at all depths occurring about every 10 days. This periodicity of about 10 days was also noted in spectral analysis of data collected in 1976 (U.S. Dept. of Commerce 1979). This periodicity was attributed to layered current patterns in the summer that, with varying depths of penetration of the geostrophic current, could cause periodic current reversals at specific depths. Since the recent data indicate that the current direction was uniform with depth, this explanation doesn't seem plausible. It is likely that the reversal in flow every 10 days is probably related to the large scale circulation in the Gulf, as an examination of the local wind record indicated no possible cause.

The continuous current measurements made between 14 February and 20 March indicated that net current flow was again to the southwest as illustrated by the PROVECS in Figure 9. The direction of flow was also quite uniform with depth, however, the average velocity decreased from 18.6 cm/sec near the surface to 11.2 cm/sec near the bottom which is about a 40% reduction in current speed. The maximum speed recorded during this 35-day recording interval was 60.0 cm/sec. The maximum speed recorded near the bottom was 42.0 cm/sec and the speed exceeded 26 cm/sec over 5% of the time. These recorded current speeds indicate that the current in the vicinity of the Buccaneer Oil Field is of sufficient magnitude to readily resuspend and transport sediments and that the direction of transport will be predominantly to the southwest.

The water currents in the area are composed primarily of tidal fluctuations superimposed on a mean current drift as illustrated in Figure 10. The tidal fluctuations were most apparent as periodic peaks in the speed data, however, variations in the measured current direction were also noticeable. The diurnal tidal fluctuations appeared to be more dominant than the semi-diurnal tide, however, the current record was too short to do a detailed spectral analysis of the results. Spectral analyses of data collected in 1976, though, indicated that both diurnal and semi-diurnal tidal components were detectable (U.S. Dept. of Commerce 1979).

Even though the tidal fluctuations were quite apparent in the current meter records, the magnitude of the wind is usually the most important driving force in water of this depth. For a comparison of the wind and currents, summary statistics for the two recording intervals are presented in Table 3. The average wind speed during the July-August 1978 recording interval was 3.9 m/sec, and the resulting

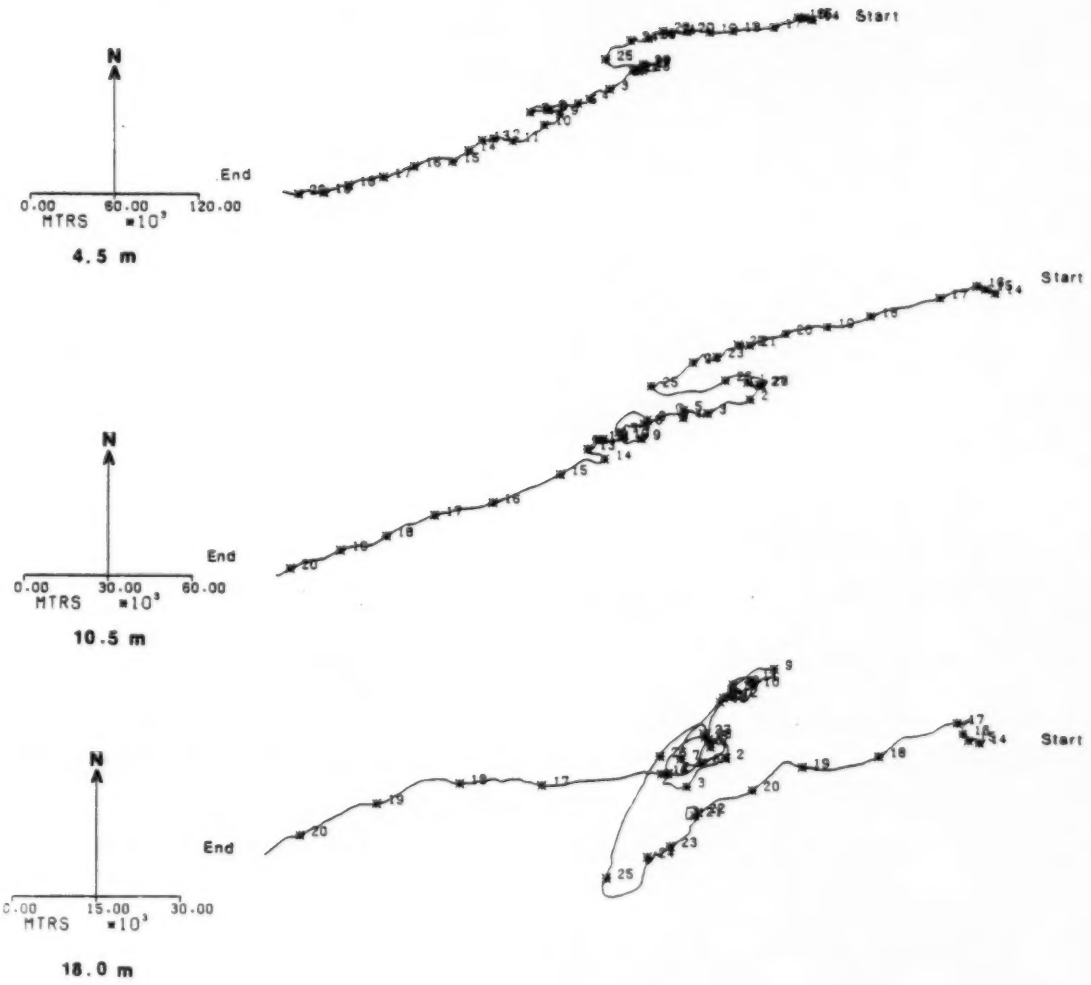

Figure 9. Progressive vector plots of the currents at 3 depths in the Buccaneer Oil Field, Gulf of Mexico, from 14 February to 20 March 1979. In order to present all three plots in the same figure a different scale was used for each.

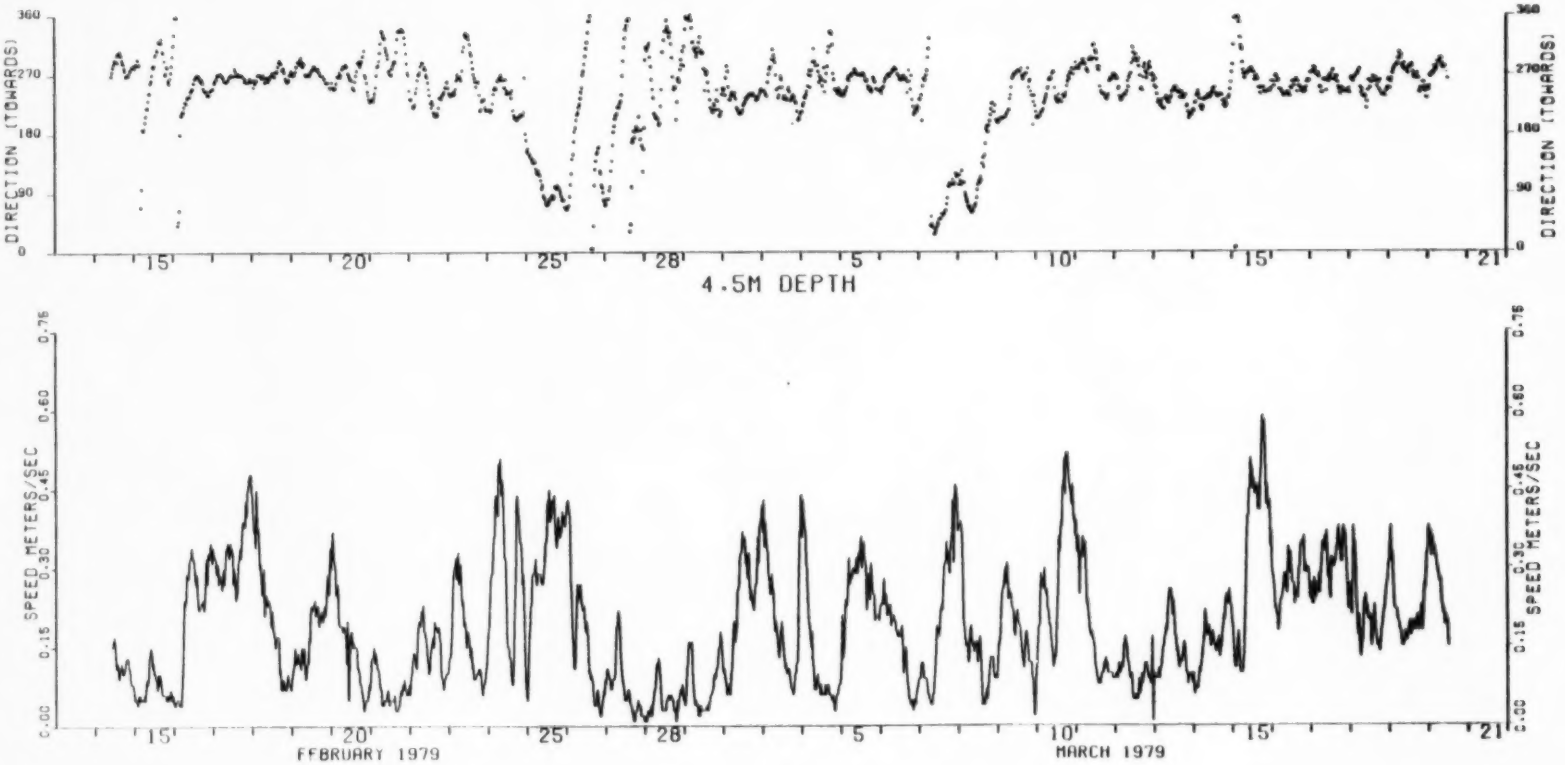

Figure 10. Current speed-direction plots for the 4.5m depth in the Buccaneer Oil Field, Gulf of Mexico, from 14 February to 20 March 1979.

Table 3. Summary of wind and currents for the Gulf of Mexico, Buccaneer Oil Field, for 26 July to 30 August 1978 and 14 February to 20 March 1979.

	Jul-Aug 78	Feb-Mar 79
Wind		
Direction (from °T)	180 (S)	045 (NE)
Mean speed (m/s)	3.9	7.1
Maximum speed (m/s)	16.1	15.2
Currents (4.5 meters)		
Mean speed (cm/s)	17.8	18.6
Maximum speed (cm/s)	62.0	58.0
Residual speed (cm/s)	3.0	13.5
Residual direction (towards °T)	185 (S)	250 (WSW)
Currents (10.5 meters)		
Mean speed (cm/s)	12.9	15.2
Maximum speed (cm/s)	57.0	60.0
Residual speed (cm/s)	4.3	9.4
Residual direction (towards °T)	235 (SW)	250 (WSW)
Currents (18.0 meters)		
Mean speed (cm/s)	7.3	11.2
Maximum speed (cm/s)	46.0	42.0
Residual speed (cm/s)	3.4	4.4
Residual direction (towards °T)	250 (WSW)	260 (W)

overall mean current speed was 12.7 cm/sec. During the February-March 1979 recording interval the average wind speed increased to 7.1 m/sec which resulted in the average current speed increasing to 15.0 cm/sec. The average surface current speed (depth of 4.5 m) during the first recording interval was approximately 4.6% of the average wind speed; during the second recording interval it was about 2.6% of the average wind speed. These values are near the generally accepted range for pure wind drift currents which is 2-3% (Sverdrup et al. 1946). This should be considered a very cursory comparison, however, as monthly averaged speeds were used, and no consideration for wind or current direction was made. Also, the effects of tidal currents were included in the monthly average current speeds.

Further comparison of the relationship between the currents and wind that were observed during the February-March 1979 recording interval is illustrated in Figure 11. In this figure the daily averaged wind speed and daily averaged current speeds for three depths are plotted for comparison. The most obvious feature of the graph is the similarity of the curves for the current speeds at all three depths. The peaks and troughs corresponding to maximum and minimum current values are remarkably uniform throughout the water column. The relative extremes in current speeds also correspond well with increases and decreases in the wind speed. There is, however, approximately a 12-hr lag for the currents to fully respond to changes in the wind. The only apparent discrepancy in the comparison between the wind and currents is the large increase in current speed on 25 February with no increase in wind speed. An examination of the raw wind data, however, indicated that the increase in current speed was the result of a change in wind direction. The wind was out of the southeast prior to 24 February and the currents were generally to the west. At 1200 hr on 24 February the wind shifted and became northwesterly; approximately 12 hr later the currents responded by reversing direction and flowing to the east. The southeasterly wind had apparently piled up the water along the coast and, with the shift in the wind, the water was released. The release of water coupled with the change in wind direction produced the easterly currents and the increase in current speed. Consequently, all the major increases and decreases in the observed current speeds could be related directly to changes in the wind. A similar response to changing wind direction was observed in November 1976 (U.S. Dept. of Commerce 1979) as current speeds up to 180 cm/sec were reported.

A comparison of the wind and current speeds measured during the July-August 1978 recording period is presented in Figure 12. The correlation between the wind and currents is not as apparent in the results. A closer examination of the original wind record, however, suggested that there was considerable interference from the platform on the measured wind field which may account for the poor comparison. The instrument was moved for the February 1979 measurements to eliminate the interference. The results from the current meters again show very good correlation between depths except for a general decrease in speed with depth. The large increase in speed on 28 August was the result of tropical storm Debra which produced currents as high as 66 cm/sec.

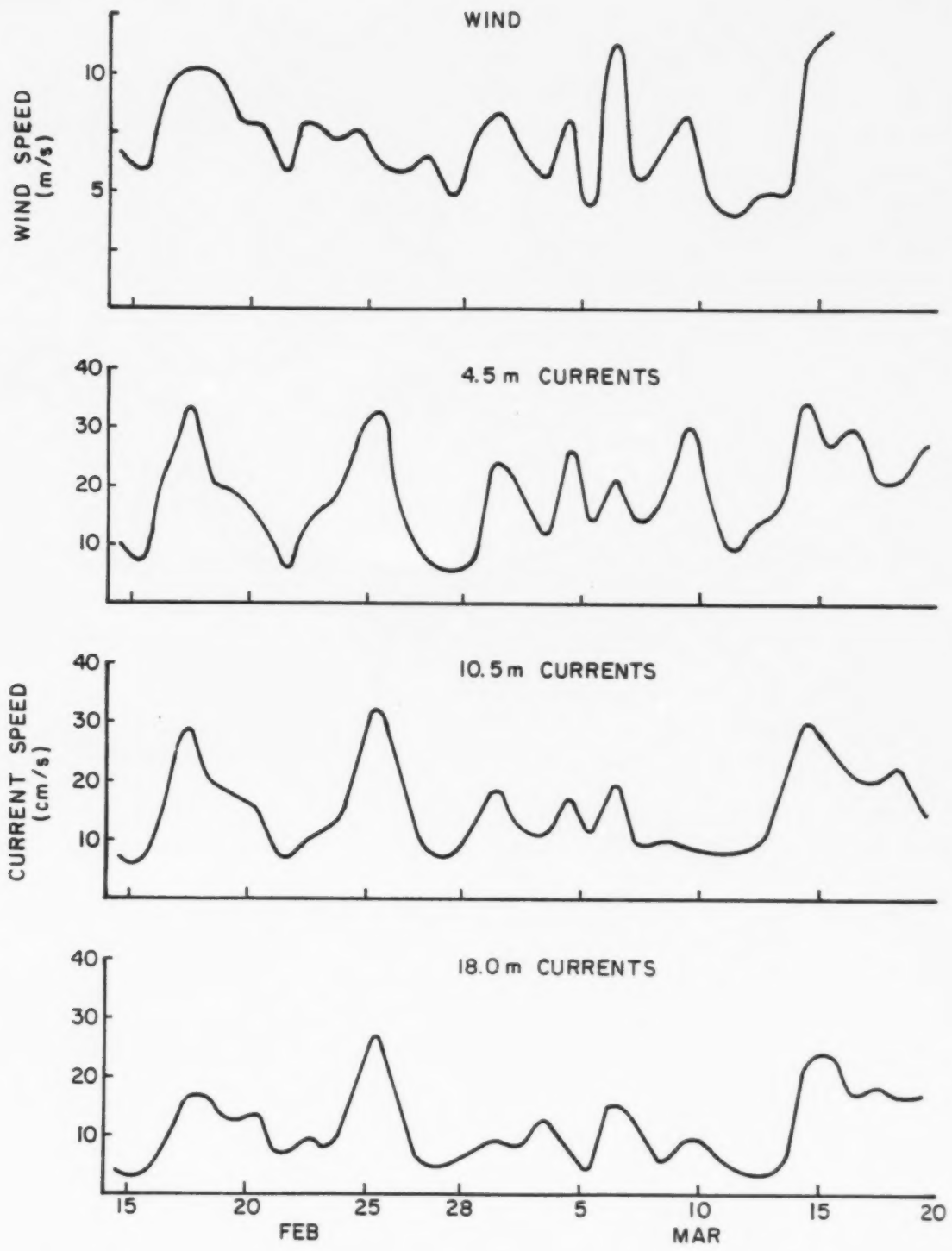

Figure 11. Daily mean wind and current speeds for the Buccaneer Oil Field from 14 February to 20 March 1979.

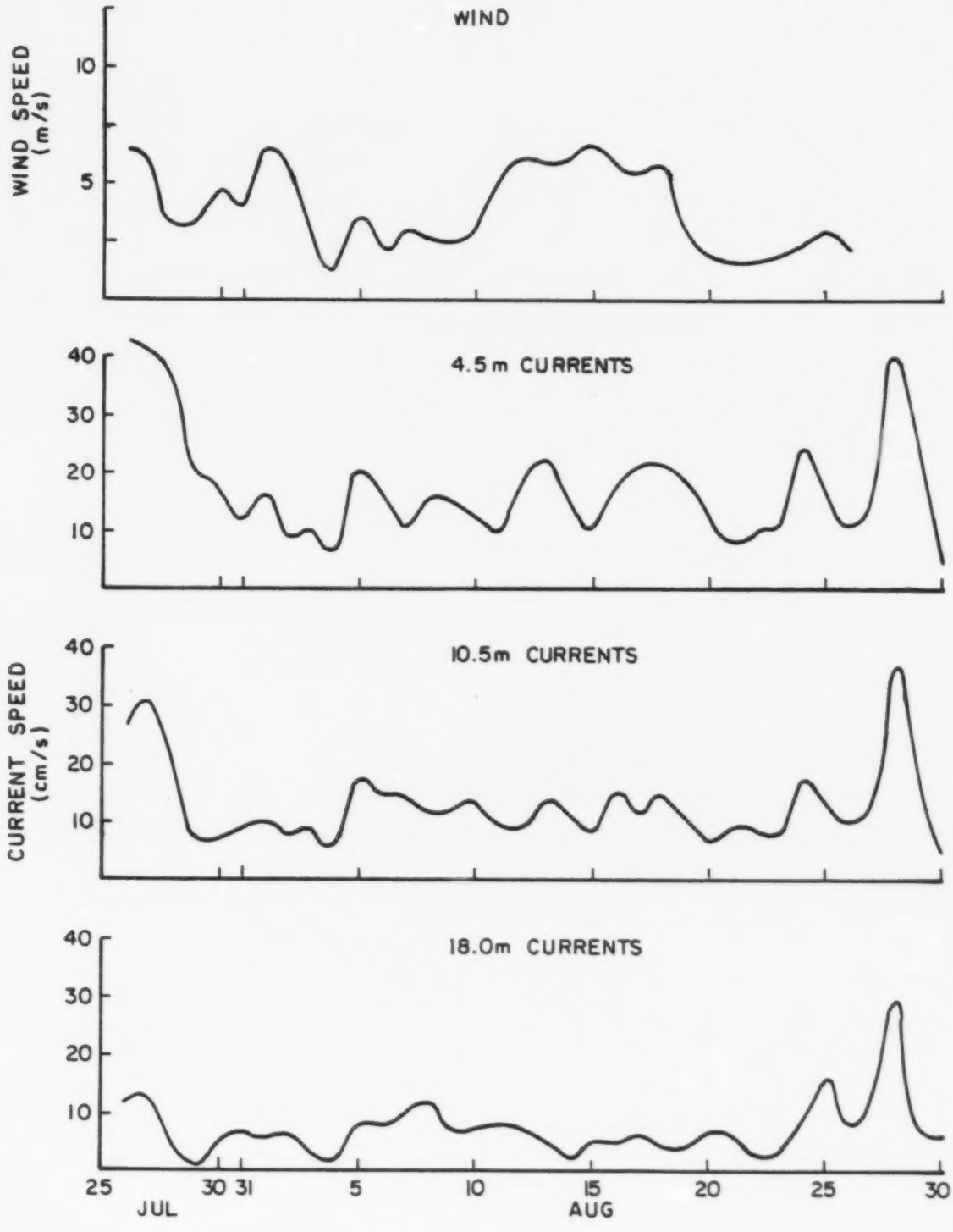

Figure 12. Daily mean wind and current speeds for the Buccaneer Oil Field from 26 July to 30 August 1978.

The electromagnetic current meter measurements taken during the four field studies also indicated that the current direction was generally uniform with depth and that the current speed typically decreased with depth. There was a reversal in flow between upper and lower layers on 26 October 1978, but this was the only time that such a velocity shear was observed. Typical examples of the velocity profiles that were observed in the Buccaneer Oil Field are presented in Figures 13 and 14. These profiles were taken on 14 February and 8 and 9 May 1979. One observation that was made during the measurements on 14 February was a considerable decrease in water velocity near the surface that occurred during the afternoon sampling. The decrease in velocity near the surface was the result of an opposing wind during the time of sampling as the currents were toward the southwest and the wind was out of the south. The general trend, however, was for decreasing current velocity with depth.

A comparison of the electromagnetic current meter measurements with the data from the continuous recording current meters indicated there was very good agreement in the measured directions of flow. Most measurements at comparable depths agreed within 20°, and the maximum difference was only about 40°. Considering that the continuous recording meters measured an hourly average and the vertical profiles were instantaneous, the agreement was quite good. The measured current speeds did not agree as well. Continuous measurements, on the average, were about 31% lower. The higher values from the electromagnetic current meter measurements were probably caused by vertical and horizontal motions of the boat during measuring and also by interference from wave orbital velocities. Consequently, the vertical profile measurements appear to be biased, somewhat, toward higher values.

Total Suspended Solids

The total suspended solids (TSS) measurements made during the hydrographic sampling indicated that the TSS values that were recorded were generally less than 5 mg/l with values frequently being less than 1.0 mg/l. The highest value that was measured was 12.0 mg/l and occurred in July 1978. The lowest values occurred in October 1979 with most of the measurements being around 1 mg/l. In general, the measurements taken during the hydrography surveys were higher than those reported for the Surficial Sediments and Suspended Particulate Matter Work Unit (Work Unit 2.3.2). The values reported for this work unit were generally around 1.0 mg/l with values rarely exceeding 3.0 mg/l.

Considerably more TSS samples were taken for the Suspended Particulate Matter Work Unit than for the Hydrography Work Unit, so those results are used to estimate suspended sediment fluxes through the Buccaneer Oil Field. The reported surface TSS values for August (Work Unit 2.3.2) averaged 0.5 mg/l, and the bottom values averaged 1.2 mg/l. Using the average currents measured in August 1978 and stepwise integrating throughout the water column results in an estimated flux of suspended sediment of about 1.92 gm/sec per meter of water surface. Using the same procedure and TSS values for February of 0.92 mg/l (surface) and 0.9 mg/l (bottom) results in an average suspended sediment

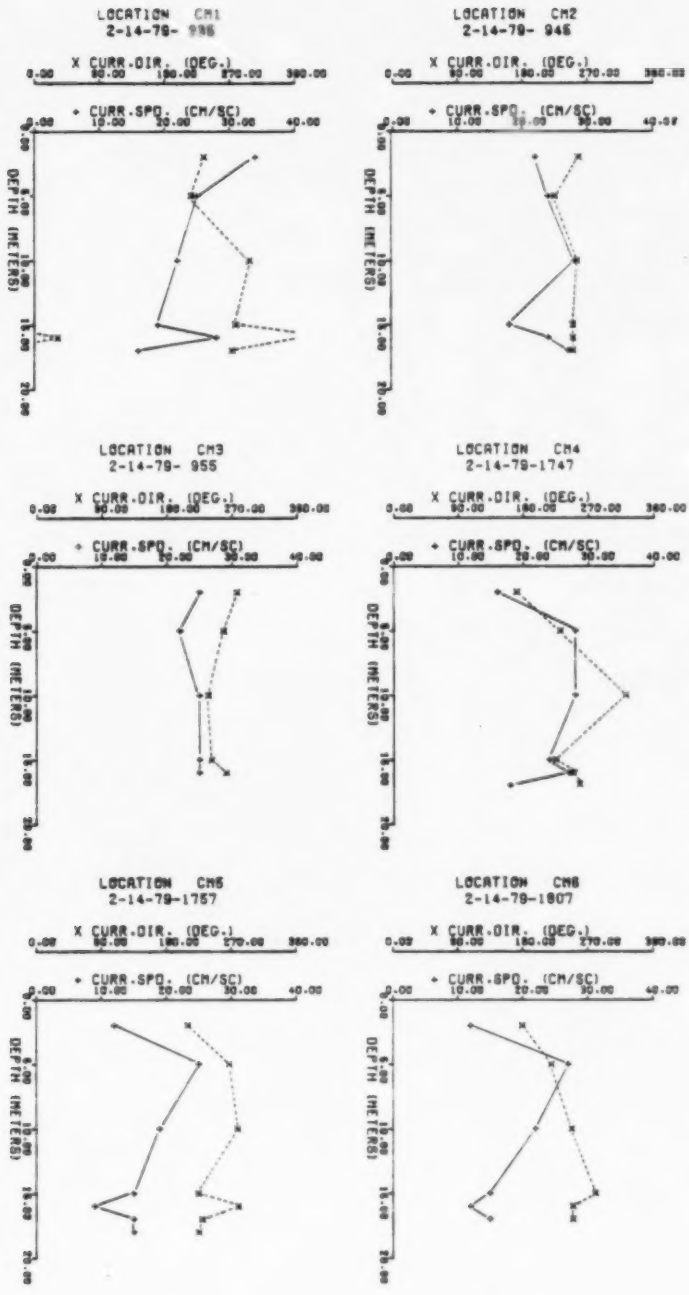

Figure 13. Electromagnetic current meter speed-direction profiles from surface to bottom in the Buccaneer Oil Field, Gulf of Mexico, for 14 February 1979. Low tide was at 11:29; high tide was at 18:23 on 14 February 1979.

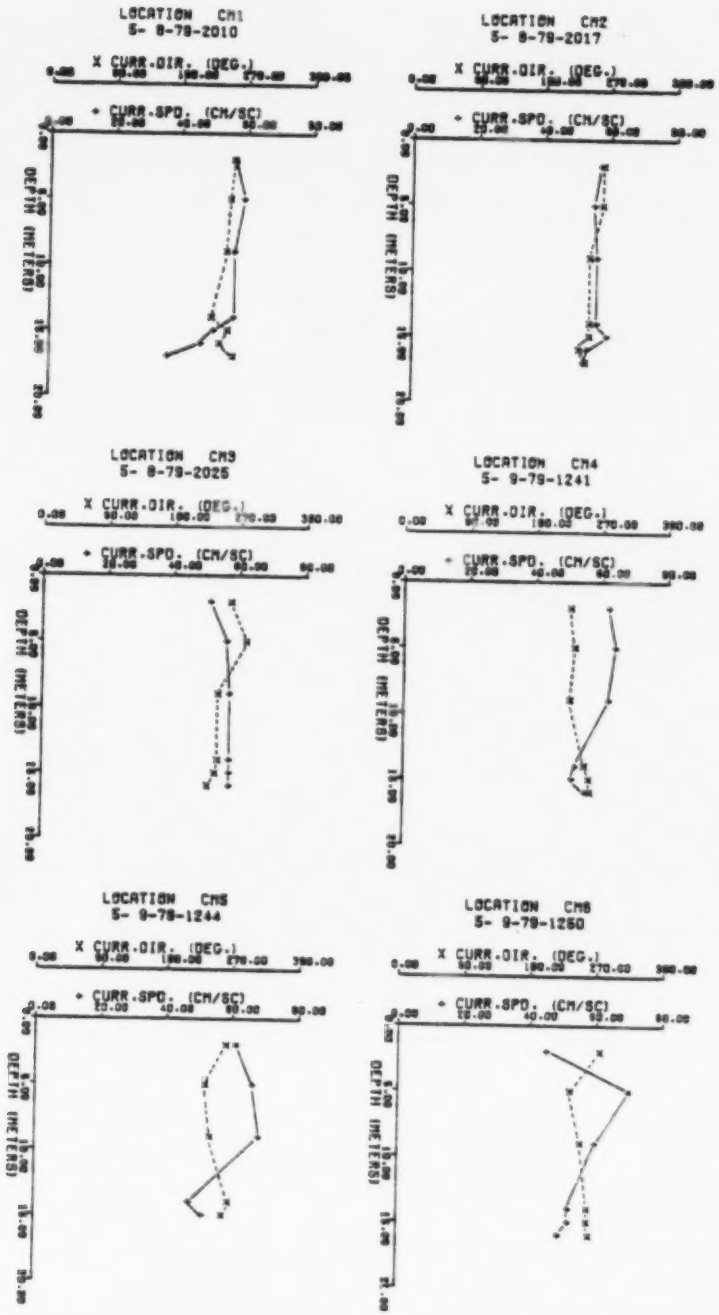

Figure 14. Electromagnetic current meter speed-direction profiles from surface to bottom in the Buccaneer Oil Field, Gulf of Mexico, for 8 and 9 May 1979. Low tide was at 20:13 on 8 May; high tide was at 14:05 on 9 May 1979.

transport of about 2.86 gm/sec per meter of water surface. Consequently, an average flux of material of about 2 gm/sec per meter of water surface can be expected at the Buccaneer Oil Field; however, this value can vary considerably under storm conditions when the TSS concentration increases and the current velocity increases. For example, on 9 May 1979 the electromagnetic current meter measurements near Platform B indicated the currents averaged nearly 60 cm/sec, and the measured TSS values varied from 2.0 mg/l to 6.4 mg/l near the bottom. This resulted in a suspended material flux of about 40 gm/sec per meter of water surface.

Wind and Waves

Wind and wave measurements were made concurrently with the current meter measurements for two month-long periods, one beginning on 26 July 1978 and the other beginning on 14 February 1979. A summary of the results of the measurements and a list of historical data for the general area are presented in Table 4. During the first recording interval the wind speed averaged 3.9 m/sec and was generally out of the south. This was similar to the expected winds for this season (U.S. Dept. of Commerce 1973) which are generally from the southeast and average 4.8 m/sec. The winds recorded during the February 1979 recording interval were much more variable, but the general direction was from the northeast and the average speed was 7.1 m/sec. The historical wind data indicate the wind from this season is generally from the southeast and averages about 6.2 m/sec.

The higher wind speeds in February 1979 generated larger waves as the average wave height in July 1978 was only 0.5 m as compared to 1.0 m for February. The maximum significant wave height that was recorded was 2.1 m that occurred on 10 March 1979 when the wind speeds reached 15.2 m/sec. The computed orbital velocities at the water-sediment interface were also greater during February as the values exceeded 20 cm/sec 9% of the time as compared to only 4% for July 1978. The maximum computed orbital velocity was nearly 40 cm/sec which is sufficient energy to readily resuspend unconsolidated sediments (Weller 1960) in the range of .05 to 2 mm (coarse silt to coarse sand). The historical wave data indicate that wave heights can reach 7 m for this area. Assuming a wave period of 8 sec for these waves, an orbital velocity of well over 1 m/sec at the water-sediment interface is possible. The available wave energy in conjunction with the water currents indicate that most unconsolidated sediments or particulate contamination from the Buccaneer Oil Field can readily be flushed from the area especially under storm conditions.

CONCLUSIONS

The results of the currents and wave measurements indicated the bottom sediments in the vicinity of the Buccaneer Oil Field are subject to considerable erosional stress. Theoretical calculations of wave orbital velocities that exist at the water-sediment interface indicate that during the two periods of wave observations the scouring velocity at the bottom exceeded 20 cm/sec about 7.5% of the time. The maximum

Table 4. Historical and measured wind and wave parameters for the northwestern Gulf of Mexico.

	Historical[a]				Measured Values for 1978 and 1979								
	Mean Monthly Wind Speed (m/sec)	Mean Monthly Wind Direction	Maximum Wave Height (m)	Wave Height ≥2m (%)	Mean Wind Speed (m/sec)	Mean Wind Direction	Significant Wave Height (m) Mean	Significant Wave Height (m) Max.	Wave Period (sec) Mean	Wave Period (sec) Max.	Orbital Velocity[b] (cm/sec) Mean	Orbital Velocity[b] (cm/sec) Max.	Orbital Velocity ≥ 20 cm/sec (%)
Winter (Jan., Feb., Mar.)	6.2	SE	4.9	11	7.1[c]	NE	1.0[d]	2.1	6.2	8.3	11.1	39.9	9
Spring (Apr., May, Jun.)	5.5	SE	7.3	4									
Summer (Jul., Aug., Sep.)	4.8	SSE	7.3	3	3.9[e]	S	0.5[f]	1.3	5.9	7.8	5.1	23.0	4
Autumn (Oct., Nov., Dec.)	6.4	ENE	4.3	15									

[a]Historical data obtained from U.S. Dept. of Commerce (1973) and U.S. Dept. of Energy (1978).

[b]Estimated maximum value of the elliptical velocity of the wave field at the bottom.

[c]Sampling period was from 14 February to 16 March 1979.

[d]Sampling period was from 14 February to 11 March 1979.

[e]Sampling period was from 26 July to 26 August 1978.

[f]Sampling period was from 26 July to 31 July 1978.

calculated speed near the bottom was nearly 40 cm/sec. Historical wave information for the area indicate that waves greater than 7 m occur in the area which can readily generate orbital velocities at the bottom in excess of 1 m/sec. The currents, however, are the primary source of sediment resuspension and transport as the current speeds near the bottom exceeded 26 cm/sec about 3.5% of the time during the two periods of observation. Previous measurements in the area showed the currents reached as high as 180 cm/sec, and historical information indicate the currents can exceed 2 m/sec. These results reveal that most unconsolidated sediments and particulate matter resulting from oil production will be periodically flushed from the area. The results further indicate that the resuspended material will generally be transported to the southwest although there is considerable variability in the direction of flow. The average rate of transport is about 2 gm/sec per meter of water surface. This transport rate, however, can increase dramatically during storm conditions.

The water currents in the area were influenced primarily by the wind and tides. Both diurnal and semi-diurnal tidal periods were apparent in the current meter records. The wind, however, was the dominant factor controlling the currents as nearly all major changes in current speeds could be related to changes in wind speed or direction. Even though increasing wind speed generally produced increasing current speeds, the currents did not always flow in the same direction as the wind, which indicates the shoreline and bathymetry were also an important influence on the currents.

The hydrographic surveys near the oil field indicated horizontal salinity variations as great as 3.4 ppt across the study area which is typical for this location. The fresher water was usually to the north and was the result of fresh water runoff from sources as far away as the Mississippi River that generally flow southwest along the coast. In July, however, the salinity gradient was reversed with fresher water to the south of the study area. This reversal was the result of a changing current system as the expected currents for July are to the northeast while during the other seasons the expected flow is to the southwest. The northeast flow in July apparently upset the general trend of southwesterly flow of freshwater along the coast and produced the reversal in salinity gradients. There was also considerable vertical variation in the salinity, especially in the spring, as fresher surface waters penetrated the study area from the north.

This one-year study of the currents and hydrography near the Buccaneer Oil Field indicated that the area can best be described as a mixing zone for coastal and offshore waters. The area is also a high energy regime with scouring from waves and currents with a potential for sedimentation during the more quiescent periods. The changing currents which are influenced by the tides, winds, and shoreline, continually change the location of the mixing zone. Consequently, the extent of the penetration of the fresh coastal water and, therefore, the distribution of salinity and temperature are quite variable. This variability in conjunction with the normal seasonal changes results in an extremely variable hydrographic environment.

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